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IMPROVEMENT OF SRL GROUND MICROPHONES

and

ASSOCIATED ACTIVITIES IN CONNECTION WITH

DEVELOPMENT OF AN IMPROVED ACOUSTIC DETECTION SYSTEM

Final Report

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Modification No. 9

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SECTION I

INTRODUCTION

I. INTRODUCTION

This report covers work that can be divided into phases as shown in the Table of Contents. These phases are not necessarily equal in importance, nor are they completely separable. ~~The~~ a capacitor microphone *was tested with temperature, humidity and pressure effects considered.* ~~Improvements stemmed from increased~~ demands upon its characteristics and from inadequacies found during initial field use. A manual was written describing the design and operation of this microphone, but this report will give some of the background on each change.

An important area ~~to be~~ studied was a reasonably accurate method of checking the sensitivity calibration of the microphone. Ideally, it should require minimum equipment, be inexpensive, and be accurate within reason. Temperature, humidity, and pressure (altitude) effects on various methods were studied. The calibration described provides a good compromise among the above factors. Atmospheric effects either do not become a consideration or they can be correlated directly to a correction factor.

The portable pistonphone is a simultaneous development that is related to field calibration. Section IV of this report, "Portable Piston- phone," will serve as a manual. It is more versatile than the field calibrator and probably more accurate. In addition to indicating the

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pressure sensitivity of the microphone, it will show the frequency response (0.3 to 30 cps).

Considerable test and comparison data was obtained on the Mark II Microbarograph. It was convenient to give this microphone the same tests as the capacitor microphone and the results were informative.

One of the pipe noise reducing filters was obtained from WSMR and preliminary investigations were made. A method of adapting one of the rain shield and leak tube assemblies was devised and is described in Section VI.

Several alternate methods of signal handling were considered. The most promising three were an FM system, a Pulse Deviation Modulation (PDM) system and a Bridged-"T" system. Sufficient sensitivity could be obtained from each[1] if a suitable, inexpensive detector system could be developed. Attention was concentrated finally on a PDM system devised from the Pulsonde flight instrument.[2,3] This model was developed and is described in Section VII.

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[1]Proceedings of the Symposium on Atmospheric Acoustic Propagation, August, 1961, "Infrasonic Capacitor Microphone Systems," Carlos McDonald, p. 119.

[2]Pulsonde Acoustical Sensing Device, April 1960, Schellenger Research Laboratories.

[3]Proceedings of the Symposium on Atmospheric Acoustic Propagation, August, 1961, "Pulsonde Telemetry System," George Q. Clark, p. 135.

SECTION II

SRL CAPACITOR MICROPHONE

II. CAPACITOR MICROPHONE IMPROVEMENT

1. <u>General</u>

During the week of February first, 1962, several problems were uncovered as a result of a field trip by Mike Izquierdo of Schellenger Research Laboratories and Dean Olson of WSMR and from subsequent work. The major problems were:

    a. Response of the microphones did not go down far enough in some microphones. Testing on each unit was only being run between 50 and 5 cycles. Low response at low frequency was usually caused by poor back-up chamber seals.

    b. Resonance occurred in some units between 60 and 120 cycles. A unit with a low resonance would then be miscalibrated at the 50 cycle test point, and the microphone response at lower frequencies would not be great enough.

    c. When the back-up chamber on the microphone was properly sealed, low frequency response was increased appreciably. However, sealing exaggerated a heat problem within the microphone. The heat problem became the prime problem.

In trying to get a flat microphone response to 0.5 cycles, a check was made of the electrical response of a number of microphones. All microphones (new model - painted red) were flat electrically to below 0.5 cycles and about 3 db down at 0.3 cycles. An attempt was made to lower the 3 db point further. However, improvements in this range are extremely hard to make and would require extensive circuit changes. Therefore, efforts at improvement were shifted to improving acoustical response at low frequency.

Tightly sealing the back-up chamber (with the exception of a small leak hole for atmospheric pressure changes) will produce a flat frequency response to 0.5 cycles. If the whole can is used as a back-up chamber, and it is tightly sealed, changes of pressure on the back of the microphone element are caused by the heat of the tubes. This did not show in the calibration box testing since the microphone was mounted without the can. In the pistonphone, heat effects noted were erroneously thought to be completely caused by outside factors such as weather fronts. The heating effect was not noticed in the first minute or two, but began to build rapidly. After extended use, with a tight seal, an output equivalent to a signal of up to ten dynes/cm^2 could be noted.

To eliminate heat in the back-up chamber, an attempt was made to have the sound enter through holes in the can and seal the original sound entrance as a back-up chamber. A resonance at 285 cycles of the can acting as a closed pipe resonator prevented this.

The next and successful solution was to provide a closed baffle as a back-up chamber. A can of the same type used in the Pulsonde microphones was mounted on a slightly modified microphone element and sealed with the exception of a controlled leak.

Some difficulty was encountered in feeding the lead wire through the baffle can. The capacitance between the can and the lead has to be much less than the capacitance of the microphone, 100μμf. The resistance

must be greater than 10^{10} ohms. It must also seal tightly. The first feed-thru used was glass-insulated with a metal shell. The shell was aluminum soldered to the can. Resistance on this type was just passable. The second material tried was a plastic, as in the following sketch.
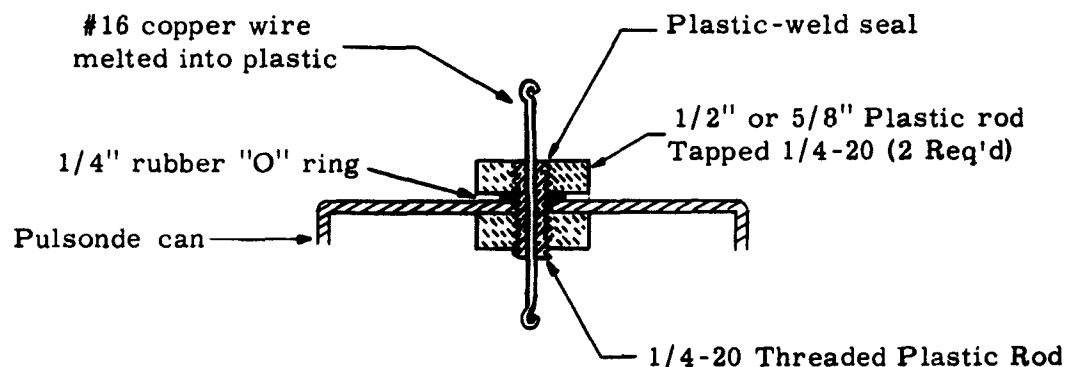
Figure 2-1
Feed-thru

This feed-thru had very high resistance and low capacitance, and was used in most of the microphones. A similar, commercially manufactured feed-thru has been found and will probably be used in later modifications to give a more reliable seal and less chance of cracking.

Previously, it was thought that styrofoam allowed passage of sound while providing a waterproof sound entrance. However, it was very difficult to make the styrofoam waterproof. Sound entered through air leaks at the edges of the styrofoam. It was found that most of the sound came in through the breather tube and the styrofoam leaks. Without the

breather tube and with the styrofoam sealed, the incoming sound was severely attenuated. With the breather tube, resonance occurred at too low a frequency -- about 75 cycles. Therefore, the top of the microphone was opened (styrofoam removed) to prevent resonance at the sound entrance.

To vent the electronic components, an additional hole was drilled approximately 5/8" from the edge of the lid, tapped, and the breather cap switched to this hole. A small piece of thin silk or nylon was glued inside the can top to serve as a dust filter at the sound entrance. Three aluminum legs were installed to allow the microphone to be inverted. This was done to protect the sound entrance from direct rain.

By the changes in the size of the back-up chamber, the sensitivity of the microphone has been reduced from 2 volts peak-to-peak per dyne/cm^2 rms to about 1.1 volt per dyne/cm^2 on the most sensitive setting. It was felt that such a sensitivity would be sufficient for the intended use.

The calibration of the microphone was also changed to facilitate field use. A sensitivity of 0.4 volts rms per dyne/cm^2 rms is now used in the first or most sensitive position. In the second position, sensitivity is 0.02 volts rms per dyne/cm^2 rms. The one and two positions are still used to record sound pressures of 74 to 100 db and 100 to 126 db, respectively.

With this sensitivity (switch position one), a signal of 100 db or 20 dynes/cm^2 gives a peak-to-peak output of about 23 volts, rather than the 40 volts of previous models. At this pressure (100 db) the output is 8 volts rms. The calibration procedure now uses this value as one test point. A 100 db input at 50 cycles produces 8 volts rms output.

A 0.1 μ f mylar capacitor has been added between the polarizing voltage of the element and ground. Such a capacitor tends to stabilize the polarizing voltage on the element. By doing so the 3 db point of the response curve is lowered between 0.05 and 0.1 cycles. For instance, the overall response is now 3 db down at 0.3 cycles instead of 0.4 cycles.

Each microphone modified was also upgraded in a number of minor ways. Extensive work was done in reattaching all components and resoldering or checking each connection. Switch position labels were installed to facilitate use. The 60-cycle ripple has been reduced by resoldering the filament plating on the board with a minimum of solder and by soldering the tube shield ground leads.

All microphone elements were completely disassembled and reworked for better durability and uniformity. The method of attaching the signal lead to the backplate was changed to prevent the lead breaking loose. Instead of soldering a nut to the backplate, a screw is counter-

sunk into the backplate and soldered over. In assembly, care was taken that no dirt or filings remain in the back-up chamber. Such material could and on previous models had worked between the mylar and backplate causing insensitivity. Silicon grease was used between the epoxy mounting board and the mylar to assure a good and lasting seal. Great care was taken with the steel clamping rings to produce good sealing and clamping by sanding and bending at critical points. A few of the last microphones modified employed an aluminum clamping ring. The aluminum could be drilled and cut without any distortion and produced exceptionally good seals. In assembling the mylar, the tension was roughly gauged on each element. The uniformity of the last 13 microphones was indicated by their requiring only very slight gain-potentiometer adjustment for proper calibration (all microphones between 1/2 and 3/4 of the full range).

Calibration after modification was much more accurate and stable. As mentioned above, components are more uniform. Calibration was done by using a standard GR mike on each microphone calibration rather than by a more indirect method previously used. Use of a particular rms voltmeter instead of an oscilloscope resulted in considerably easier reading and thereby more accurate calibration. With a lower microphone sensitivity less distortion occurred in the amplifiers resulting in better linearity. Tests indicate that the microphone is

linear in at least the ranges provided -- 74 db to 126 db. In addition, more points are given on each calibration record so that a curve may be plotted on each individual microphone. As a result of much increased care and uniformity, the lower 3 db point on any curve is between 0.25 and 0.4 cycles. Before modification, the lower 3 db point had been somewhere between 0.5 and 5.0 cycles. All tests indicate that vibration, humidity, and pressure drops have little if any effect on calibration or response. In general, the modified microphones are much more durable and reliable.

On February 13, 1962, four preliminary models incorporating most of these changes were delivered to John Coffman at White Sands Missile Range for testing under operating conditions. Changes were made and five more completed models were delivered to John Coffman on February 27, 1962. An additional four models with all modifications were picked up by Dean Olson on March 8, 1962, for testing at Fort Monmouth, New Jersey.

On March 21, 1962, eleven microphones were received from Fort Monmouth for modification. All modifications were made and the microphones tested. Very little trouble was encountered in any test indicating a consistent and reliable microphone.

Thirteen modified microphones were subjected to a shake test for 1-1/2 minutes on a paint shaker which oscillates around the center

of the microphone can about 7 times a second through about 34°. This test produced no appreciable change in calibration or response in any of the microphones. Eleven of these microphones were returned by truck to Fort Monmouth, New Jersey, on March 29, 1962. Two modified microphones were delivered to John Coffman at White Sands Missile Range on March 30, 1962.

Several other areas of improvement are possible, but are not now considered desirable when weighed against the benefits obtained and the difficulty of making the change. They are stabilization of the cathode follower to prevent the slight drift present, direct coupling of the signal to obtain lower frequency response, and redesign of the circuit board for better ground paths and reduction of AC ripple.

During the early part of April, work progressed on the writing of the instruction manual for the SRL capacitor microphone, Model 2. On April 23, 1962, John Coffman requested that sixteen Model 1 microphones be rebuilt into Model 2's. Additional parts were ordered and each microphone completely rebuilt using new circuit boards and a majority of new components inside. The rebuilt microphones are identical with Model 2 microphones previously delivered and are designated by their original number followed by -2. Twelve completed microphones were delivered to John Coffman on May 7, 1962.

Further testing during April showed that the upper frequency response of the microphone was somewhat different than the response was previously thought to be. A new response curve is shown in Figure 2-2. This curve, below 100 cycles, is very similar to the curve in the March monthly report. The curve in the March report was obtained by putting the microphone inside a calibration box, and adjusting the input to the speaker at one end for a constant sound level on a standard microphone at the other end. The microphone happened to fit into the calibration box in such a way that a null was obtained at the microphone element at about 300 cycles. More tests were performed in the anechoic chamber and the curve in Figure 2-2 was obtained. The response does peak at 250 and 425 cycles but these peaks are well above the range of the microphone that is used -- 0.5 to 100 cycles.

2. Replacement Tubes

In rebuilding the old microphones, more investigation of the tube in the first stage was required. It was found that no CBS 7247 tube tested gave a low enough plate voltage to keep the neon bulb from firing. Previously over half of the RCA 7247 tubes would be satisfactory with regard to plate voltage. However, late shipments of this tube have been erratic. Some lots yield 100% and some yield less than 10% suitable tubes. General Electric 7247 tubes all gave a satisfactory plate voltage.

Figure 2-2

TYPICAL FREQUENCY RESPONSE

FREQUENCY (Cycles per Second)
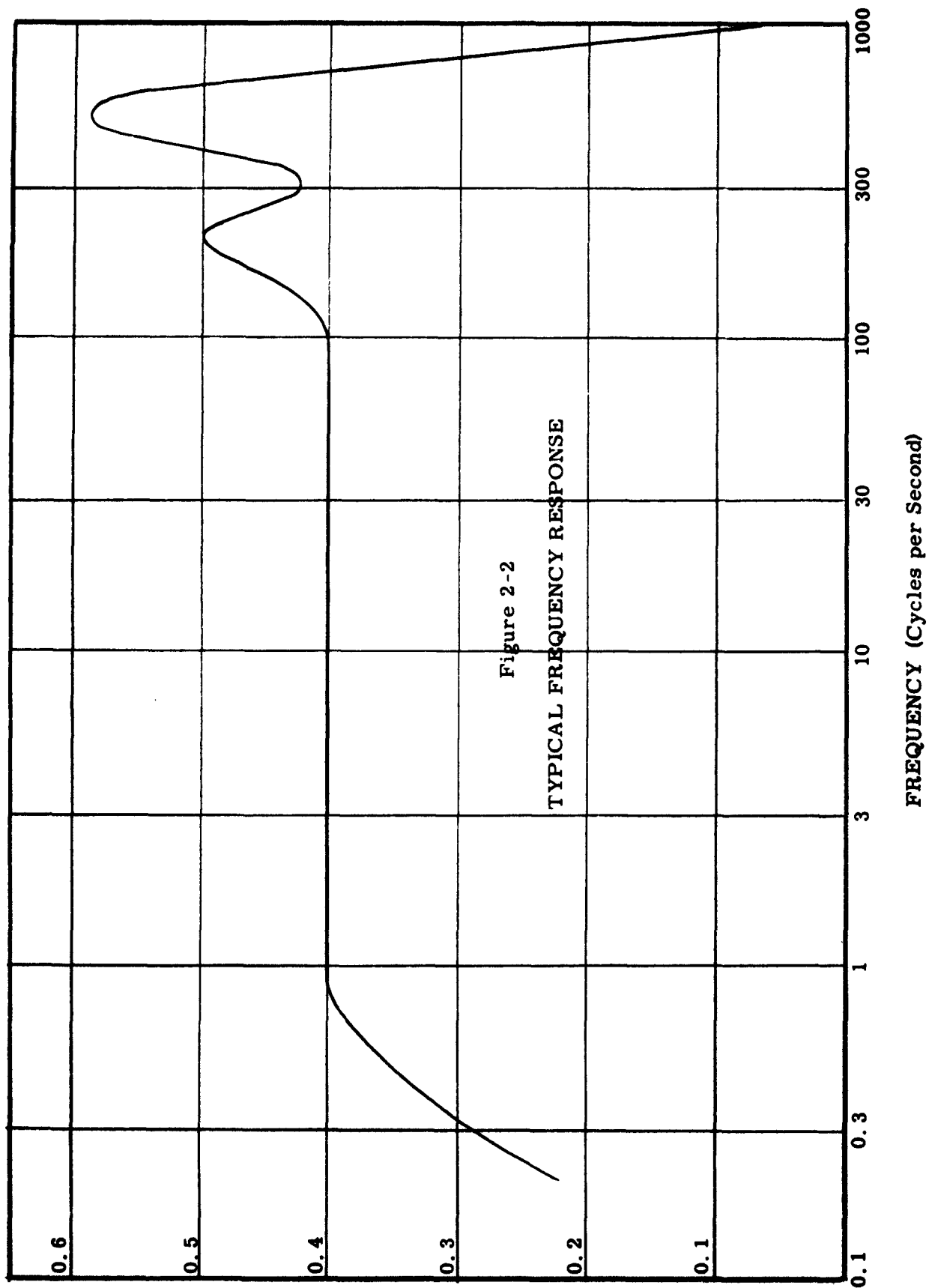
However, some G.E. tubes gave unacceptable microphone response. Switching from G.E. to RCA tubes in the first stage improved the response from 3 db down at 0.75 to 3 db down at 0.33 in some cases. A Mullard 7247 tube produced desirable plate voltage in almost every case and a good low frequency response. It appears that Mullard is the best tube for the first or microphone tube. The second tube may be replaced with any of the brands mentioned with satisfactory results.

3. Drift Problem

At the request of John Coffman and Dean Olson of WSMR, a further study was made of the drift problem in the microphone system. It has been noted before[*] that variations in voltage to the power supply will produce a random low-frequency drift in the microphone. Normal variations in line voltage usually cause less than 1 volt (peak-to-peak) microphone output at a frequency less than 0.25 cps. However, starting a large motor (heater or air-conditioner) may cause 4 or 5 volts microphone output.

This drift is caused primarily by changes in the filament supply voltage. A given percentage change in the line voltage will change the filament voltage by approximately the same percentage, since the

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[*] Chapin and Chew, "Monthly Progress Report," 1-31 March, 1962.
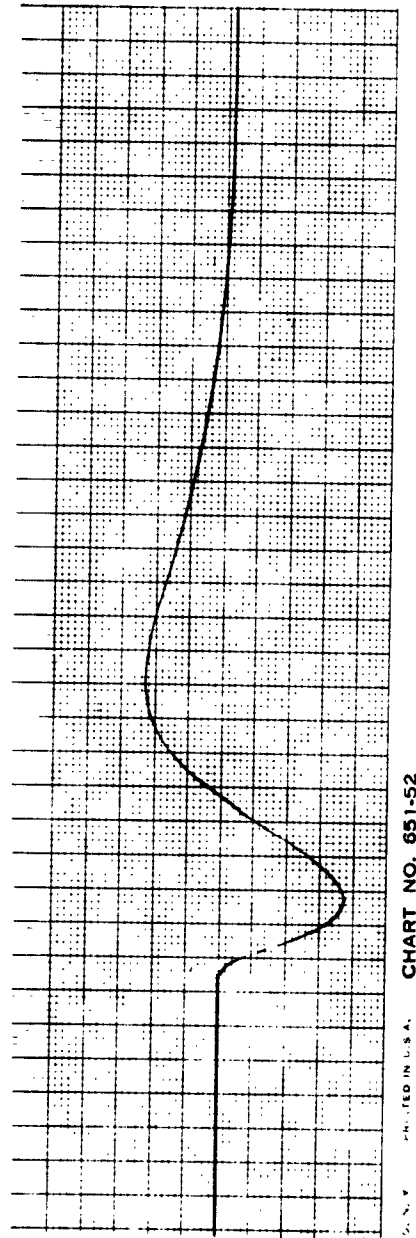
Figure 2-3
Microphone Response to Filament Voltage Change
(Chart speed--5 mm/sec., Sensitivity--0.5 volts/mm)

CHART NO. 651-52

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filament supply voltage. A given percentage change in the line voltage will change the filament voltage by approximately the same percentage, since the filament supply is unregulated. A rapid voltage change causes a slower fluctuation in the filament current due to the resistance of the filaments and their heating rate. As the filaments heat, they increase the emission of the tubes and thus change the output. Since any such signal is amplified through the microphone, the output signal produced is much higher than the change in filament voltage. The amplitude of the output is dependent upon the tubes used and the microphone amplification. It may vary somewhat from microphone to microphone.

An experiment was run with the microphone on a battery supply. A near step-function reduction was made in the filament voltage with a series resistor. The output signal is shown in Figure 2-3. The time at the bottom of the chart was marked at the instant the voltage was reduced from 5.5 to 5.1 volts. The microphone output is about 13 volts peak-to-peak for a 0.4 volt filament supply change.

The amount of output signal is dependent on the frequency of the line change as well as its amplitude. A slow line voltage change of several minutes duration will produce almost no signal output.

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Changes in line voltage can also affect the B+ circuit, but to a much less degree. By isolating various parts of the B+ supply with a battery and injecting a signal, it was found that the last tube is most affected by any B+ changes that might happen to pass the power supply regulator tube. The second amplifier tube in the microphone is affected about three times as much as the output cathode follower. However, at least 75% of the drift is due to the filament supply rather than the B+.

The solution to this problem is to either regulate the line voltage or the filament supply. The filament supply draws about 0.5 amps current. With such a high current and low voltage, it would be extremely difficult to regulate the filament supply. However, the line voltage may be regulated by equipment which should be available at sites where the microphones are used. If the drift is high in relation to the signal, the use of a line voltage regulator is urged.

4. June Microphone Construction

Eight Model 2 microphones were delivered to White Sands on July 10, 1962. Four were rebuilt Model 1 microphones and four had been Model 2 microphones returned from Fort Monmouth for modification.

5. Pressure Effects on Microphone Sensitivity

Extensive tests have been conducted on the SRL microphone to determine how its sensitivity varies with pressure.

Figure 2-4 shows the results of these tests. Note that a decrease in atmospheric pressure does cause a slight increase in sensitivity. The increase or decrease in sensitivity is relatively small.

Figure 2-5 shows the change in sensitivity expected from extreme pressure changes (maximum and minimum on record) at any one location compared to the total sensitivity at that location. Of course most changed would be much smaller than these extremes.

During these tests, the recently completed pistonphone[*] was adapted to provide measurable overpressures within. Such added flexibility permits microphones to be directly calibrated for use at any desired average atmospheric pressure. Much more accurate calibrations are now possible.

Microphones Checked: Four microphones and power supplies were checked and recalibrated for WSMR. Three of the microphones were preliminary test models which needed some revision and resoldering of hastily installed components. The microphones had been in field use for six months in an unfinished condition. All microphones were still working properly although the sensitivity was somewhat high on two microphones.

Power Supply Ripple: In two of the power supplies inspected for WSMR,

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[*]Chapin and Chew, "Monthly Progress Report," 1-31 July 1962.
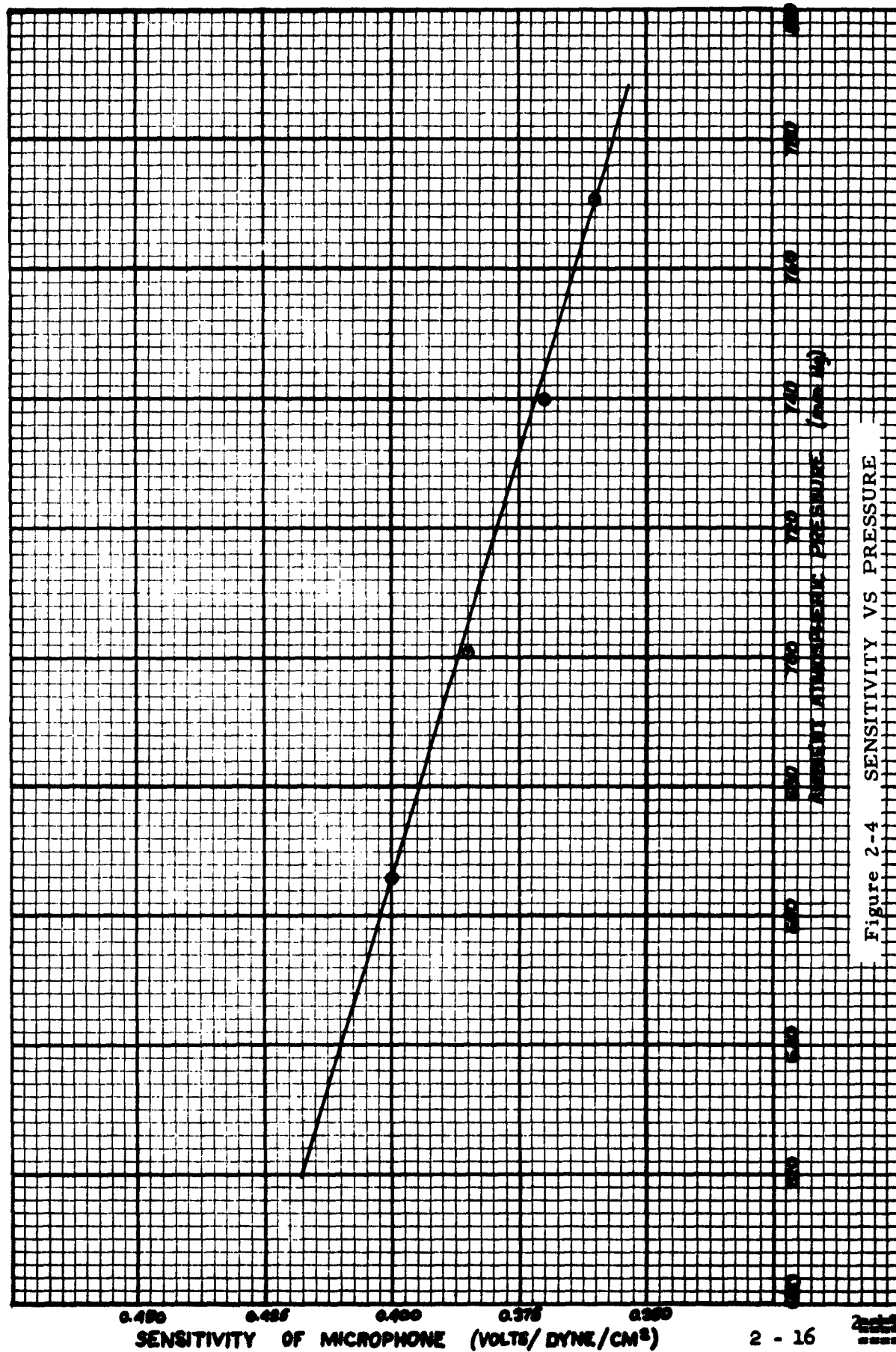
Figure 2-4   SENSITIVITY VS PRESSURE

SENSITIVITY OF MICROPHONE (VOLTS/ DYNE/CM²)

2 - 16

EXTREME MICROPHONE SENSITIVITY CHANGES
AT NEW YORK AND EL PASO

Based on all time recorded high and low barometric pressures
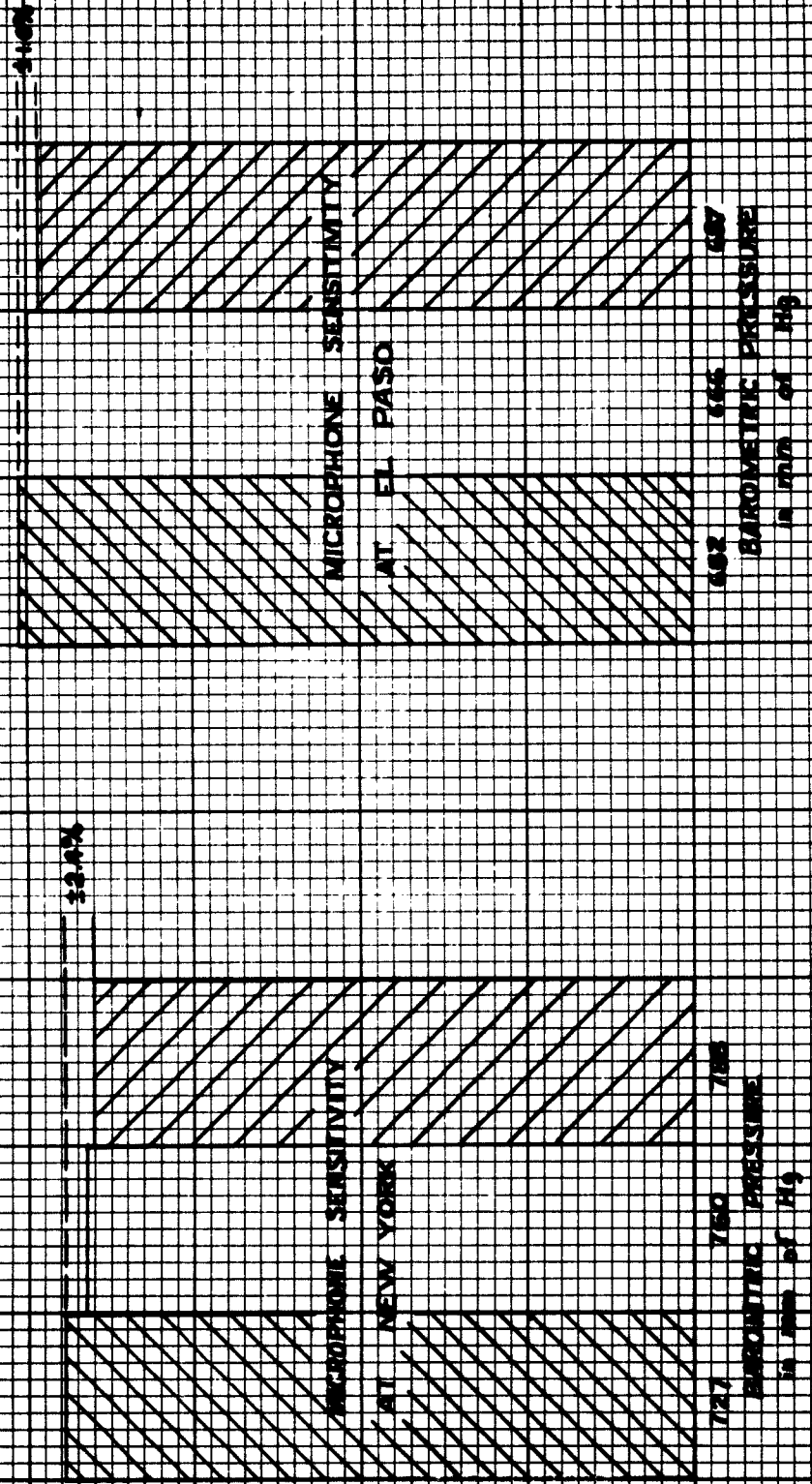
Figure 2-5

a slightly high level of 60-cycle ripple was noted. One power supply produced 140 millivolts of ripple (peak-to-peak). The maximum allowable ripple is 80 millivolts. It was found that carefully resoldering each connection in the filament supply section (6 VAC) particularly on the 0.32 henry choke coil will substantially reduce the level of ripple. Replacing the two capacitors (C3 & C4) may also be necessary.

System Noise: In working with extremely small signal amplitudes, even a small amount of noise in the microphone system or on the transmission lines is objectionable. At White Sands, the signal is of almost the same amplitude as the 60-cycle ripple in the microphones, although the frequencies are considerably different. Two ways to lessen this noise are to use filters or a battery operated microphone. Battery operation of microphones has worked quite well for laboratory testing at frequencies under one cps. Of course, batteries are less convenient, less stable, and more expensive. A notch filter for 60 cps has been constructed for White Sands. It does attenuate signals slightly but is flat below 30 cps. However, with a filter, the broad-band characteristic of the microphone is partially lost.

6. New Circuit Board

A new circuit board was developed for the microphone in the hope of decreasing the noise in the microphone system and obtaining more

durability. With the present microphone board and a properly oper-
ating power supply, a microphone ripple output of 25 to 80 millivolts
peak-to-peak is noted with no acoustic signal. Since White Sands is
looking for acoustic signals which produce only a 0.1 volt (100 milli-
volt output), further improvement in the microphone was desirable.

Two major changes were incorporated in the new board (see
Figure 2-6). The filament supply now enters each tube at pins 4
and 5 with pin 9 grounded, instead of the reverse. All ground paths
are improved with much wider plating where necessary. The tube
sockets are no longer used as ground paths but the shields are still
grounded. The board supports and lid are no longer used as a ground
path.

The combination of these and perhaps other changes reduced the
output ripple to about 1/10 of normal ripple. A microphone with a new
board produces 5 millivolts of ripple compared to 50 millivolts of an
old board. A defective power supply caused 200 millivolts ripple in
an old microphone and 15-20 millivolts in a new one.

In addition, two large capacitors formerly mounted hanging from
the board are now firmly held on top of the board, thus increasing
durability.

Normally, the ripple voltage produced by the old circuit boards
will be well below voltages produced by very light winds. The present
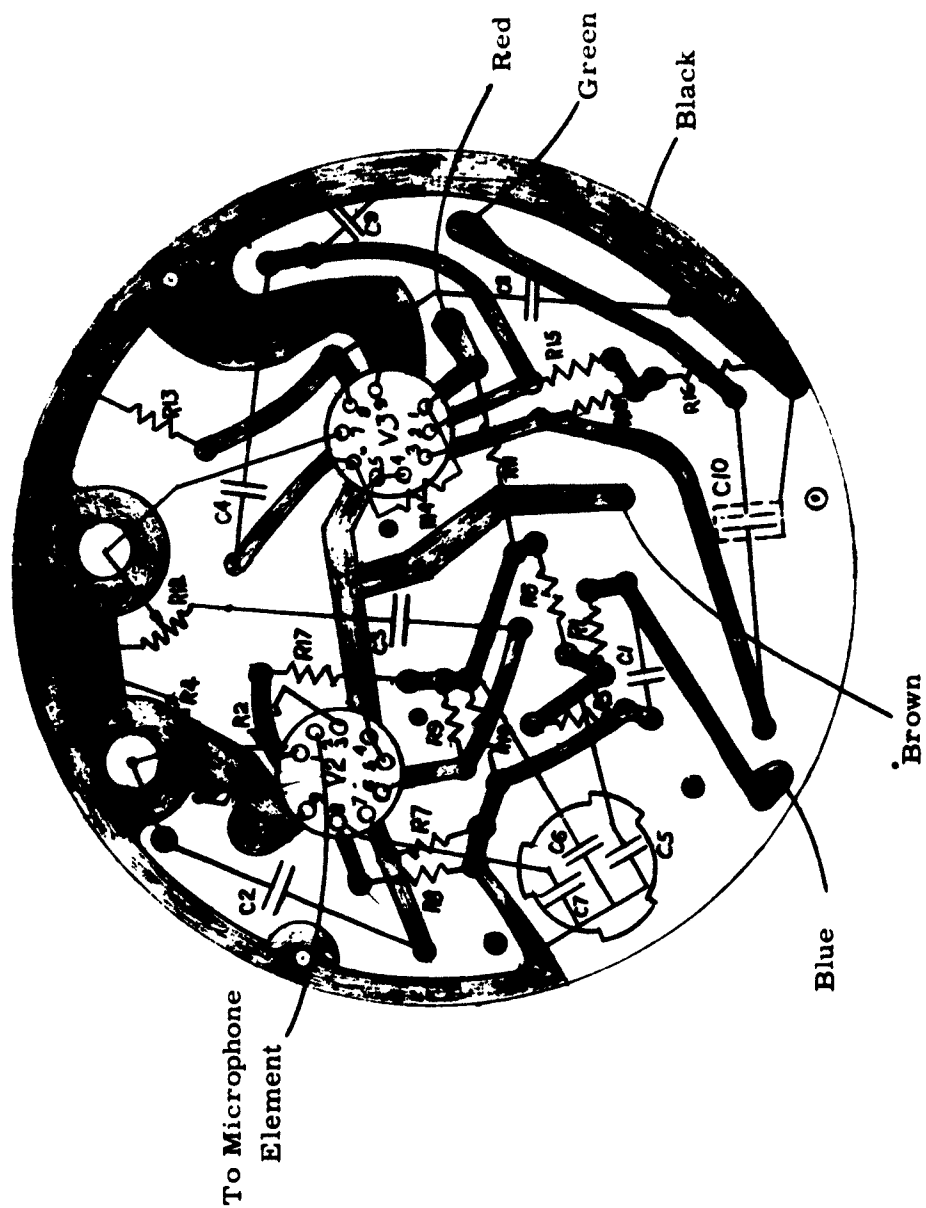
Figure 2-6
New Circuit Board

microphone can be used in almost all cases, but for extremely low acoustic levels, the new circuit board offers distinct advantages.

7. Model II Microphone Sensitivity Variation with Changes in B+

For situations where it is not practical to use the A.C. power supply on the Model 2 microphone, a battery pack can be used as described in the manual on pages 7 and 8. If the B+ voltage cannot be exactly obtained, then the included chart can be used to determine the sensitivity at various voltages. Voltages above 160 volts and below 120 volts are not recommended and every effort should be made to obtain as near 150 volts as possible since the majority of the tests have been conducted with this voltage. Another consideration, when using batteries for the B+, is to use one with a low enough internal impedance. If the cell is too small, then there might be a tendency to oscillate ("motor-boat") or to change the low frequency character-istics of the microphone. The chart plots a sensitivity coefficient vs. the B+ voltage. Simply multiply the sensitivity (nominally 0.4 volts/dyne/cm^2) by the coefficient corresponding to B+ voltage (see Figure 2-7).

8. Microphone Phase Shift

During the month of December the NASA pistonphone (capable of producing ultra-low-frequency sounds) was adapted for use in phase-relation studies. A microswitch was installed next to an eight-inch

2-21
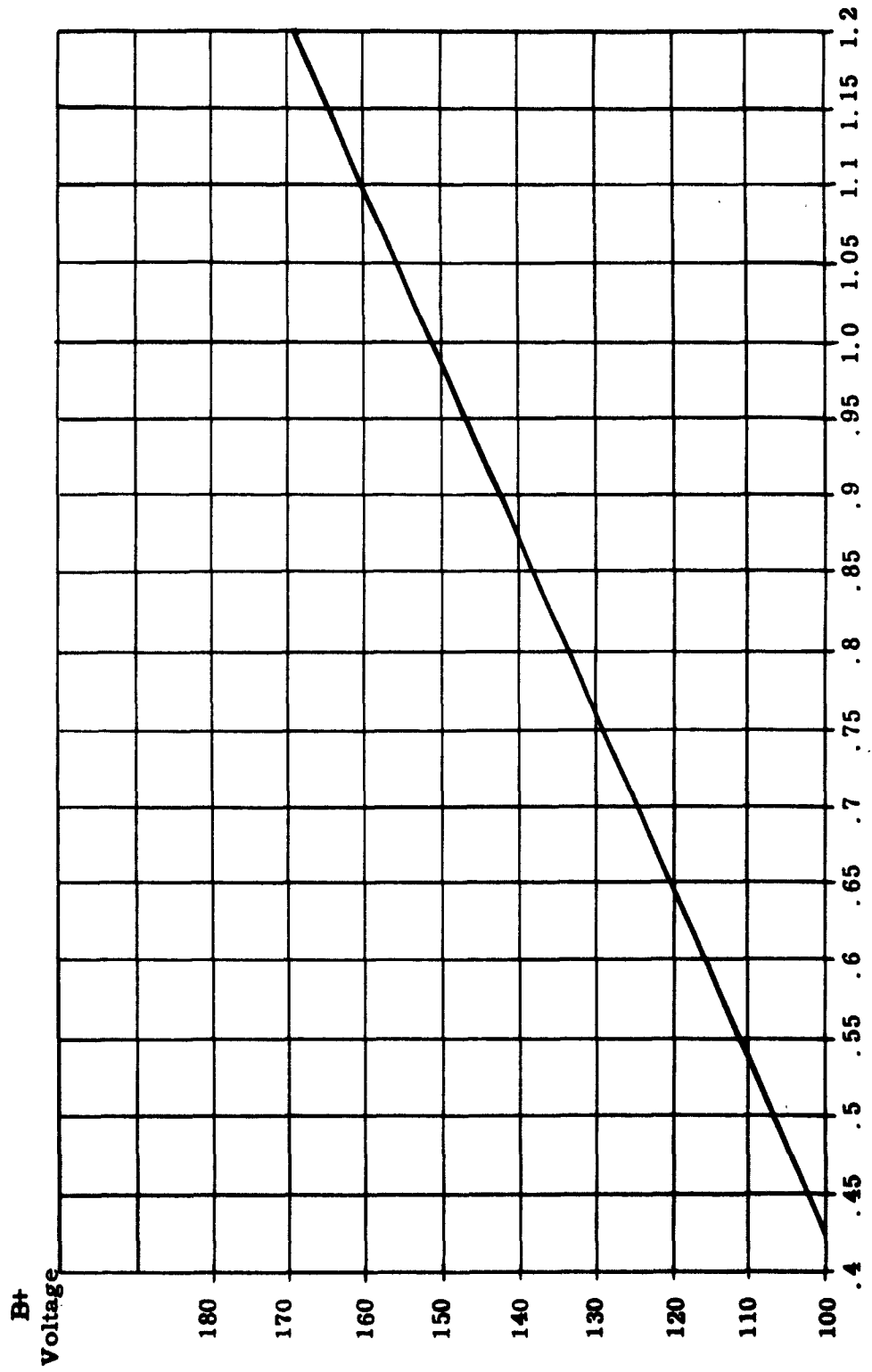
Figure 2-7
Sensitivity Coefficient
Sensitivity Vs. B+ for SRL Model 2 Capacitor Microphone

flywheel with a small bump on the flywheel surface. In conjunction with a battery and resistor, the microswitch produced a voltage spike at a fixed point on each cycle. The point was determined mechanically as 90° ahead of compression. The pulse and microphone output were then displayed simultaneously on a Sanborn recorder (see Figure 2-8).
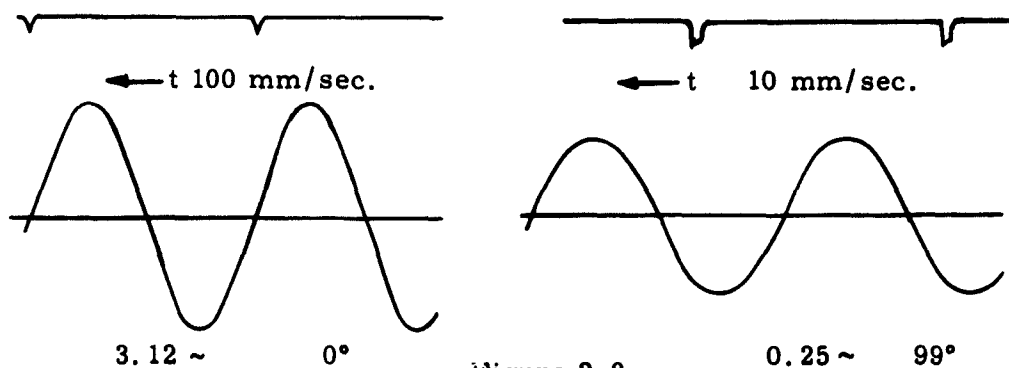
Figure 2-8
Recorder Traces

It was found that in the mid-frequency band (between about 3 and 70 cycles) the microphone is in phase with the sound pressure; a compression produces a positive microphone output. The response of the microphone begins to decrease at about 1.5 cycles. (See microphone manual, page 12.) However, a phase shift is detectable starting at a slightly higher frequency -- 3 cycles (see Figure 2-9). The phase shift was plotted to 0.2 cycles after which readings became inaccurate due to microphone fluctuations caused by powerline variations. At 0.2 cycles a 126° phase shift was noted with the microphone voltage leading the applied sound pressure.

Figure 2-9
Microphone Phase Shift
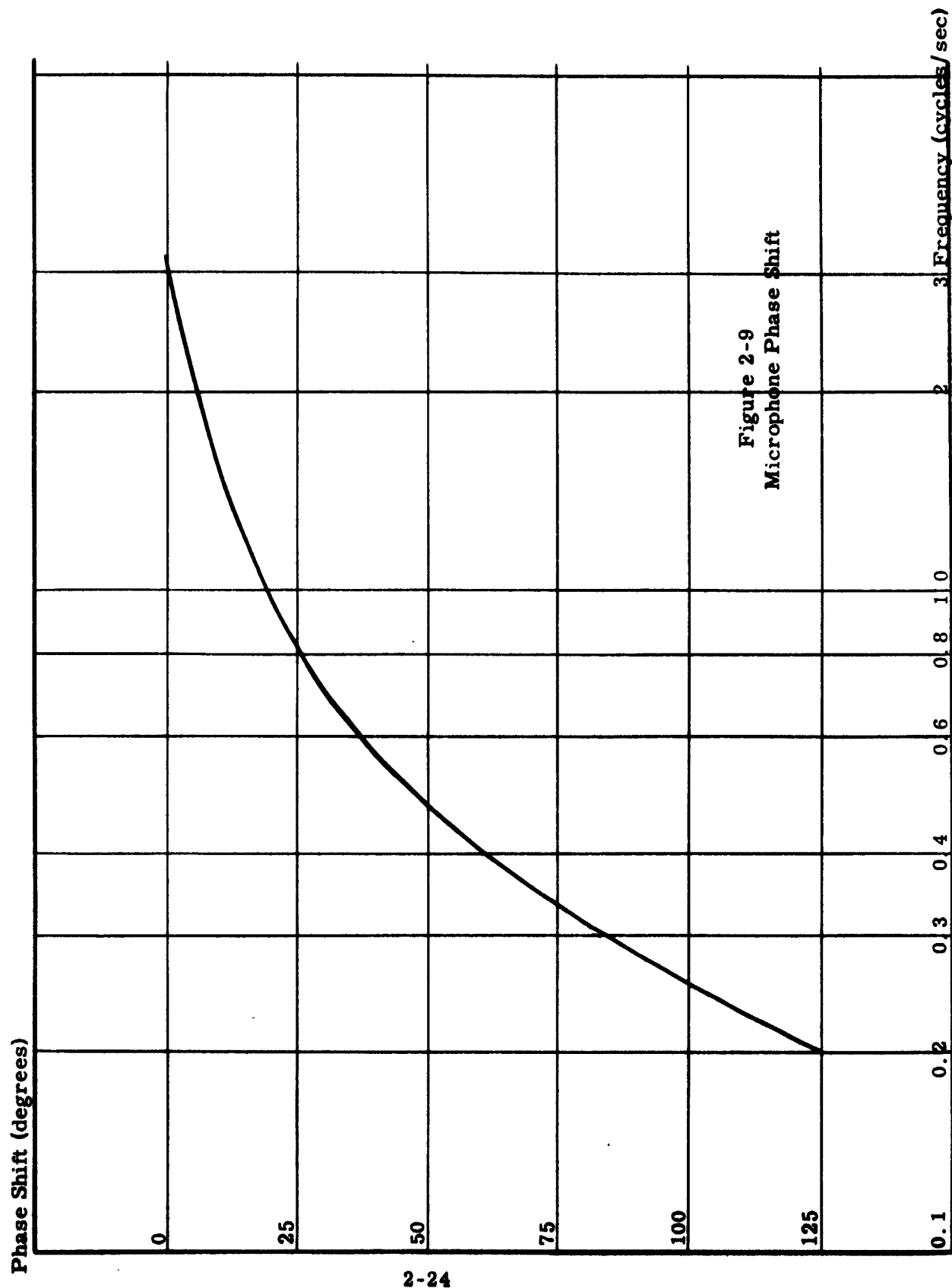
It might be well to note that a phase shift of 450° is theoretically

possible in the microphone. There are four series capacitors, C_2,

C_3, C_4, and C_{10}. The microphone element may also be considered

a series capacitor. Thus the maximum phase shift is 90° for each of

five capacitors. Since the microphone capacitance (with the grid-to-

ground resistance of V2a) primarily determines the microphone response,

the primary factor causing a phase shift at about two cycles is the com-

bination of the microphone and first tube.

A phase shift has also been noted in the acoustically tuned micro-

phone mentioned in previous reports. The phase difference increases

as the microphone response decreases, with increasing frequency. As

yet, the phase change has not been accurately determined and plotted.

9.. <u>Model 2 SRL Microphone</u>

Manual: The technical manual for the SRL Capacitor Microphone, Model 2,

has been completed and delivered to White Sands. While it was designed

primarily to describe the method of operation, it also includes basic

theory of operation and trouble-shooting sections. Attention is called,

in repetition to the statements in the manual, to the change in microphone

sensitivity resulting from almost any repair to the microphone. Schellen-

ger Research Laboratories is interested in any criticism of the manual

whether it concerns lack of clarity, an omission of needed data, or

typographical errors.

Calibration: The characteristics of the field calibrator are still being studied. While it seems to be an easily usable system in the component reliability, effects of varying temperature and atmospheric pressure, and tolerance to high humidity, must be determined before field use is recommended. In effect, this calibrator's principal function is to check the microphone element, since the electrical response can be checked as described in the manual (Section III-A4, page 11).

Sensitivity Variations: It has been noted that different power supplies will have slightly different power supply voltages to the B+ and filaments. The B+ voltage, controlled by the regulator tube in the power supply (OA2) may vary between power supplies from 146 to 152 volts depending upon the characteristics of the OA2. This voltage does not depend on the AC line voltage (under normal conditions) but only on the regulator tubes and is constant for any given power supply. Tests were therefore made to determine how such changes affected the microphone sensitivity. Generally it was found that such an extreme change (4%) in the regulator voltage would cause about 1 1/2 times as much change in the sensitivity (6%) or about .5 db. Although this variation is not normally significant, it should be kept in mind when computations are to be made of absolute sound levels or when calibrating microphones.

The filament supply voltage will vary with changes in AC line voltage. As previously noted, such a change will produce a signal

output from the microphone. However, the sensitivity of the microphone

is relatively unaffected. A 6% change in filament voltage changes the

sensitivity by an amount not readable, less than 1%.

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┌──────────────────────I M P O R T A N T──────────────────────┐
│                                                                │
│      We suggest that every microphone and power supply be      │
│                                                                │
│   checked after each month of operation.  See Section III A6,  │
│                                                                │
│   page 13 and 14 of the manual for specific procedures for     │
│                                                                │
│   checking the level of 60-cycle ripple.  Check the voltages   │
│                                                                │
│   to the microphone.  The B+ (red terminal) voltage should be  │
│                                                                │
│   146-152 VDC.  The filament (yellow terminal) voltage should  │
│                                                                │
│   be 5.8 - 6.3 VDC with the microphone connected.  As soon     │
│                                                                │
│   as a field calibrator is available, calibration should be    │
│                                                                │
│   checked with the microphone connected to the line on which   │
│                                                                │
│   the microphone will be used, thus checking the complete      │
│                                                                │
│   system.                                                      │
│                                                                │
└────────────────────────────────────────────────────────────┘
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SECTION III

FIELD CALIBRATOR

III. FIELD CALIBRATOR

1. Preliminary Model

An early method of calibration studied was a small loudspeaker closely coupled to the microphone element with a given frequency at a specified voltage applied. This gives a spot check at one frequency and one pressure level. The accuracy obtained by this method is on the order of ± 5-10%, probably not sufficient, if calibration is required at all. The immediately apparent problems are the consistency of the speaker and repeatability of close-coupling. The amount of leakage around the speaker and the volume between the speaker and the microphone need to be constant. A test figure is shown in Figure 3-1.

2. Final Model

In the May report, a method was discussed for calibrating microphones in the field by closely coupling a loudspeaker to the microphone element. A spot check of the calibration at one frequency and pressure level could then be made. However, the method was unsatisfactory because of its inherent inaccuracy. It was difficult to obtain a consistent seal around the coupling connection. More important, the volume of the cavity between the microphone element and the speaker varied from one microphone to another.

Microphone

Speaker

To Oscillator
& Voltmeter

Matching
Transformer
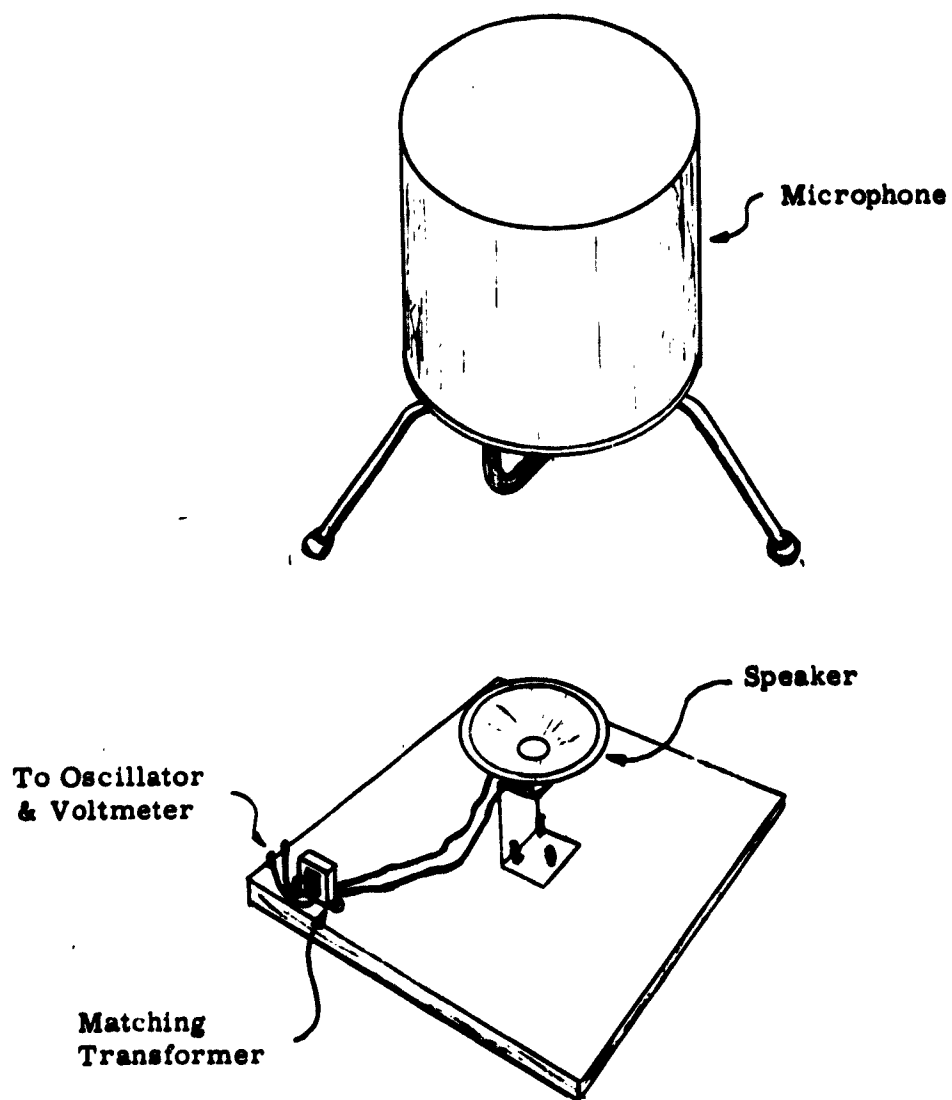
Figure 3-1

Prototype Field Calibrator.

To minimize this problem, the calibrator was completely re-designed. The preliminary model was tested on a group of nine representative microphones for consistency. The error noted was less than ± 2%. Three more models were built to determine the simplest construction. The present model is shown in Figure 3-2.

Note that the speaker has been coupled to the microphone element by a duct. The duct increases the enclosed volume over the closely coupled calibrator by about 5:1. Thus the variation in the volume of the microphone element cavity which caused difficulty in close coupling, is reduced by a factor of five.

A cover has been placed on the back of the speaker to protect the speaker from foreign materials and damage. Changes in calibrator output due to temperature variation are minimized by operating the speaker into a relatively closed volume on each side. (Small leaks are present to equalize atmospheric changes.)

3. Field Calibrator Testing

Extensive testing was conducted in August on the field calibrator. This calibrator was tested against a standard microphone and a pistonphone for reliability under different conditions of atmospheric pressure, temperature, and humidity. In a pistonphone, using a previously tested microphone, it was found that the calibrator output increased with increases in pressure as shown in the graph of Figure 3-3.
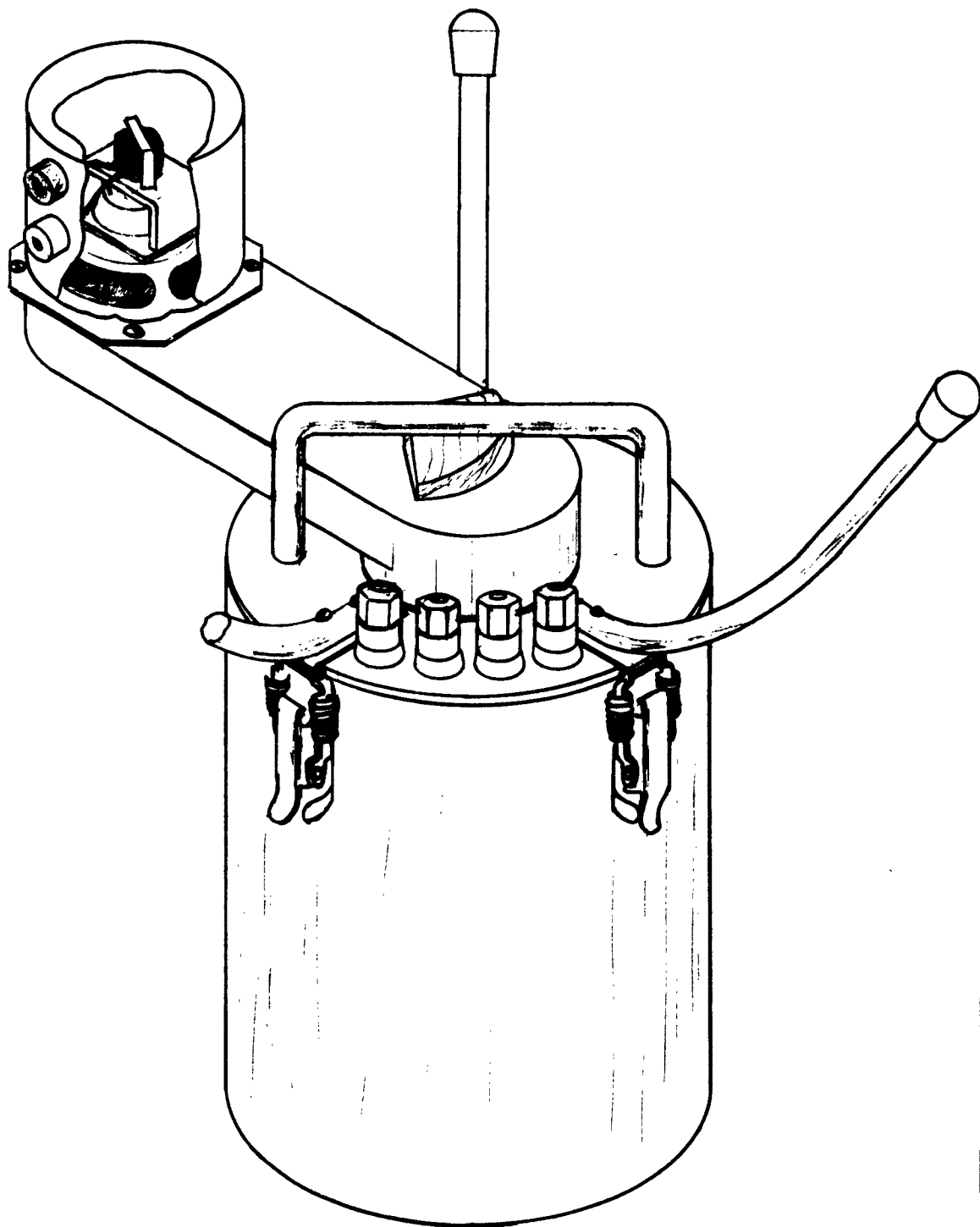
Figure 3-2. Field Calibrator

3-4
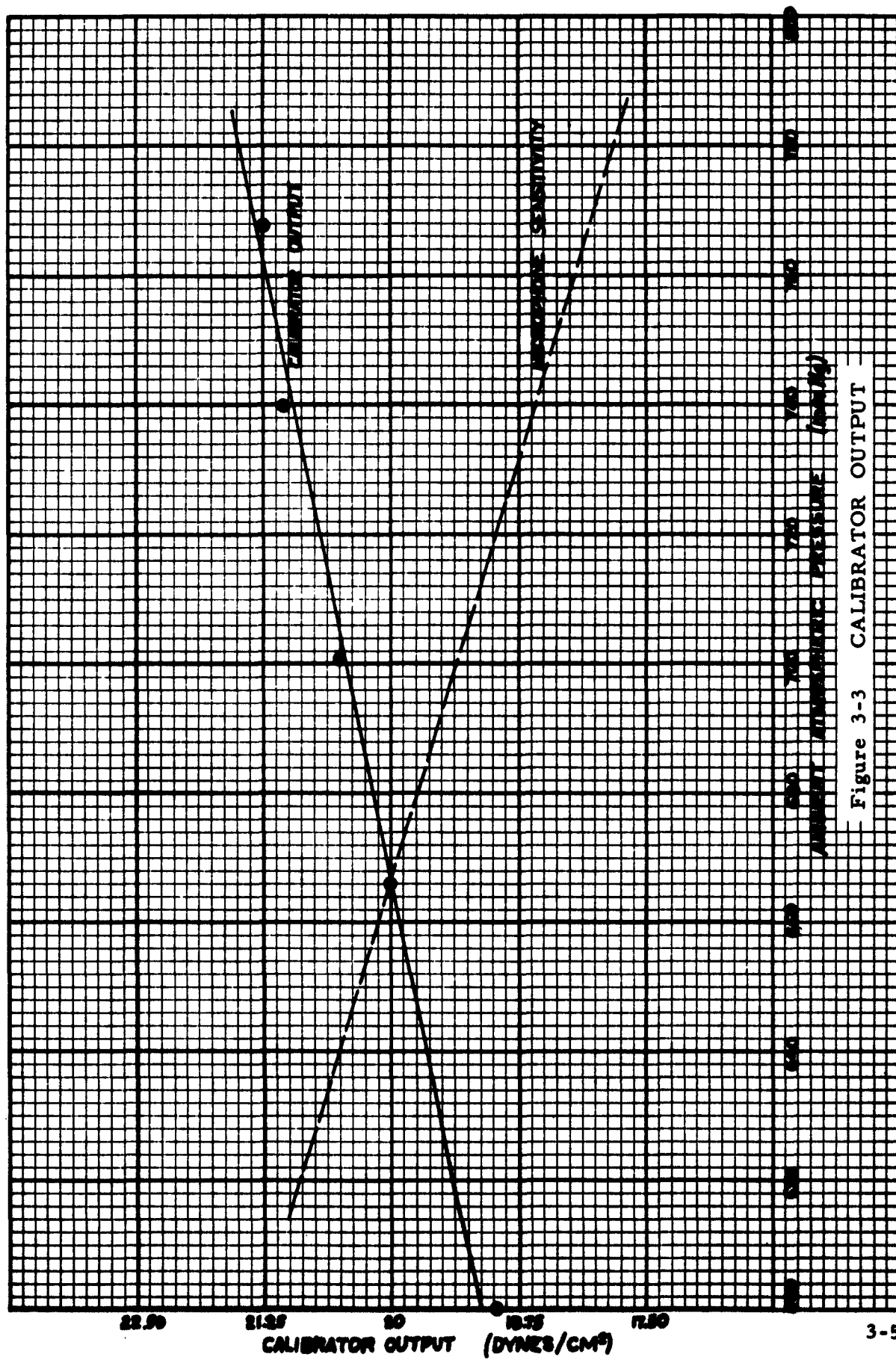
Figure 3-3   CALIBRATOR OUTPUT

The dotted line in Figure 3-3 shows the microphone sensitivity. Note that as the microphone sensitivity decreases, the calibrator output increases. The two effects tend to cancel each other so that the output from the microphone at any atmospheric pressure encountered at a field station is essentially the same. Such a property makes the calibrator easier to use in that it does not need to be corrected for atmospheric pressure--the correction is built into the calibrator.

A second consideration is the effect of temperature on the calibrator. Figure 3-4 shows that the calibrator is affected by changes in temperature. However, the change in output over wide ranges in temperature is rather small, ± 5%. If precise calibration is required, a chart will be provided to determine the calibrator output.

The third consideration of calibrator reliability is the effect of humidity. Figure 3-5 shows curves of two humidity extremes of calibrator output vs. frequency. Note that by choosing a test frequency of 20 cps for the calibrator, most of the changes in calibrator output can be eliminated.

4. Calibrator Output

A model of the field calibrator has now been made which performs favorably so far as temperature and humidity are concerned. Preliminary test of changing the calibrator temperature from 70°F to about 100°F produce no noticeable change in the calibrator output. Extremes
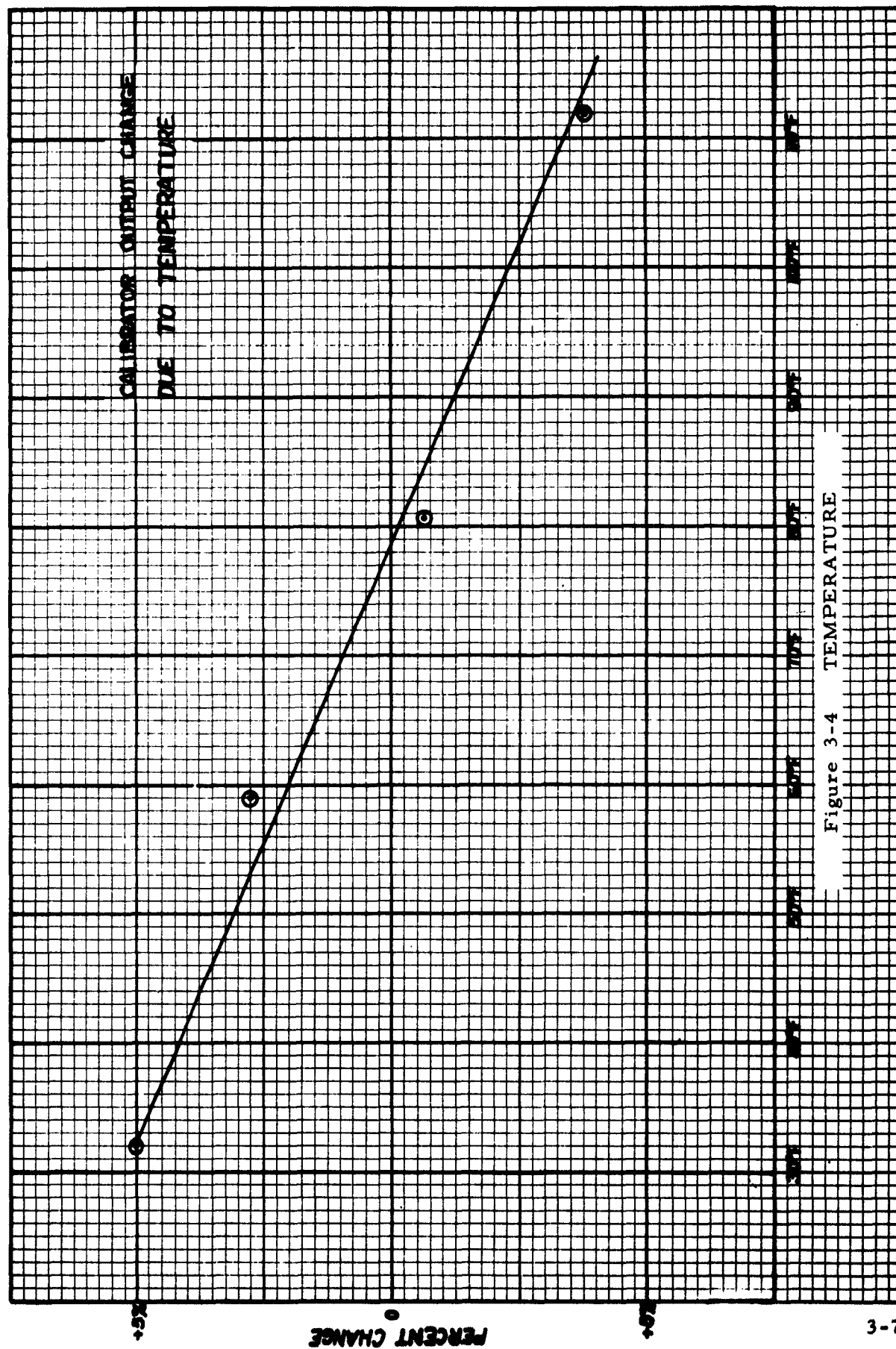
Figure 3-4   TEMPERATURE

Figure 3-5   FREQUENCY
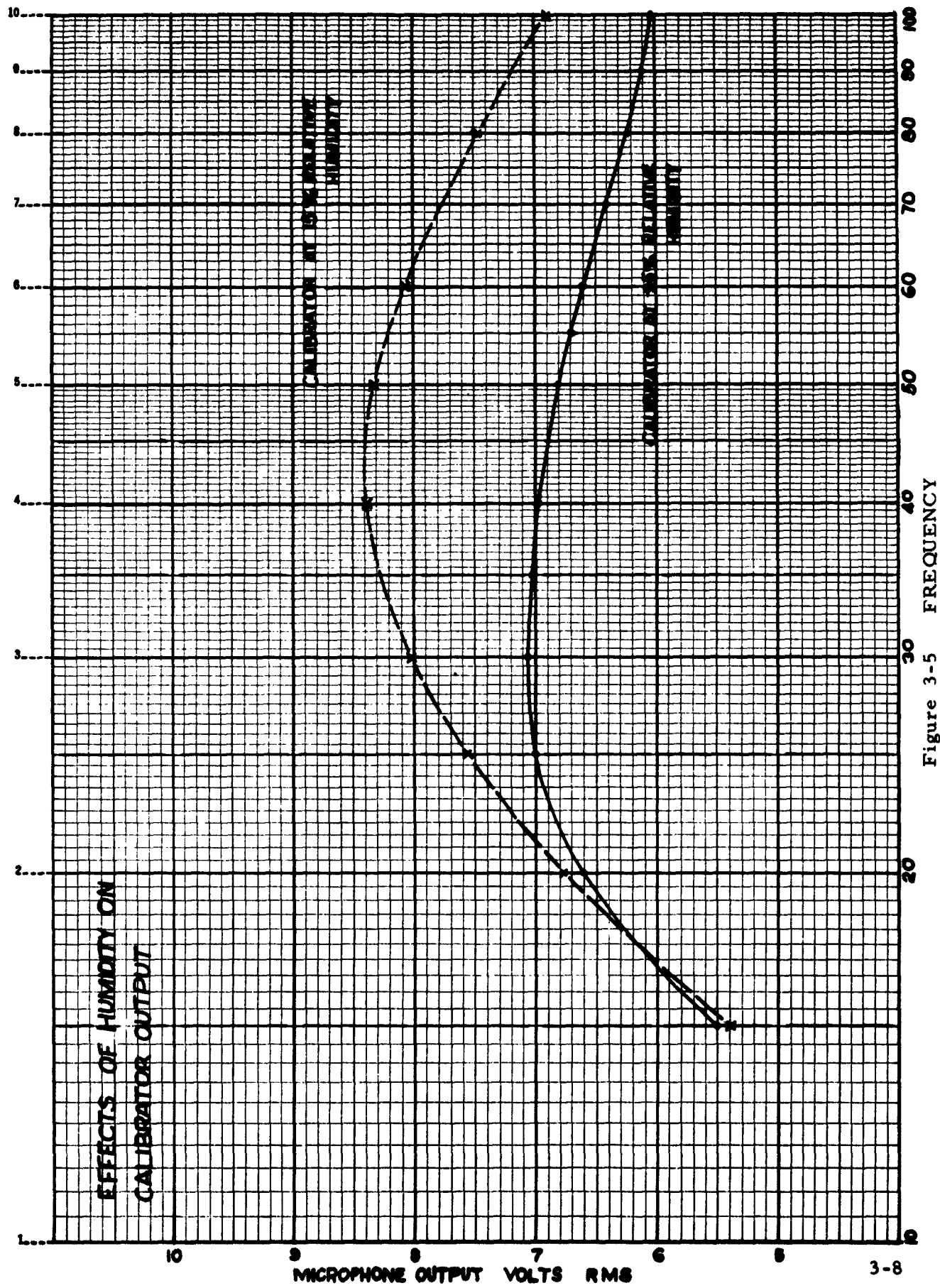
in relative humidity on this calibrator now give about a plus or minus 0.5 db change in output, with the higher output under the higher humidity conditions.

The increased stability under varying humidity conditions was accomplished by spraying the speaker cone with clear Krylon, thus causing less mass loading of the cone by the absorption of moisture. Evidently the spider supporting the cone still absorbs moisture and becomes less rigid. Thus humidity has the opposite effect depending upon whether or not the cone is sprayed with Krylon. Possibilities still exist to reduce humidity effects even further.

It has been decided to calibrate the field calibrators and the microphones for the average barometric pressure (altitude) at El Paso, Texas, of 666 mm Hg. The microphone at this pressure will have a sensitivity of 0.4 volts /dyne/cm^2 (rms) at 666 mm Hg. Microphone output will then be 8.0 volts rms.

At another atmospheric pressure, sea level for instance, the calibrator voltage for an accurate calibration would have to be found from Figures 3-6 or 3-7.

If it is desired to recalibrate the microphone for its original sensitivity (see dotted line), the voltage specified on the calibrator should be multiplied by a factor read from Figure 3-6. To determine this factor, find the average atmospheric pressure on the horizontal

scale, proceed up to the solid line, and over to the left hand vertical

scale.   The output of the microphone is then adjusted for 8.0 volts rms.

Multiply Calibrator   Microphone Sensitivity
   Voltage by   (volts/dyne/cm^2)

Ambient Atmospheric Pressure (mmHg)
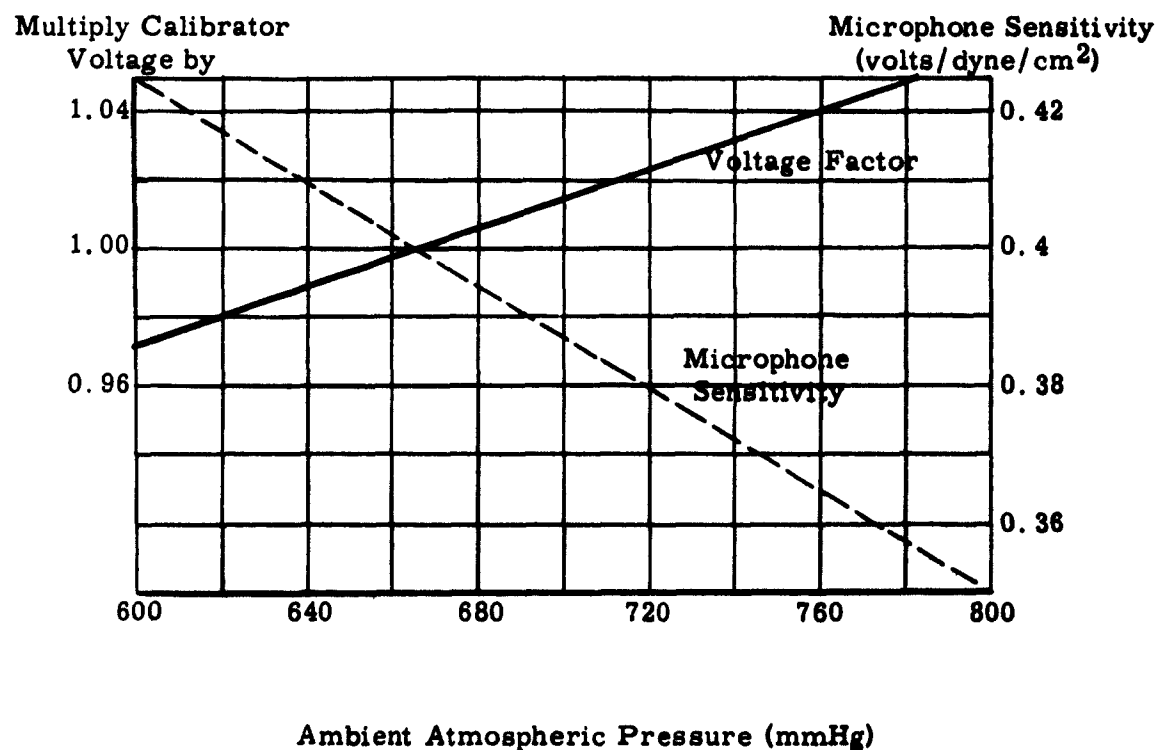
CALIBRATOR VOLTAGE FACTOR (original microphone sensitivity)

Figure 3-6

If it is desired to recalibrate the microphone for a sensitivity of

0.4 volts/dyne/cm^2, Figure 3-7 should be used in the same manner.

The output of the microphone is again adjusted for 8.0 volts rms.

Multiply calibrator
voltage by

Ambient Atmospheric Pressure (mmHg)
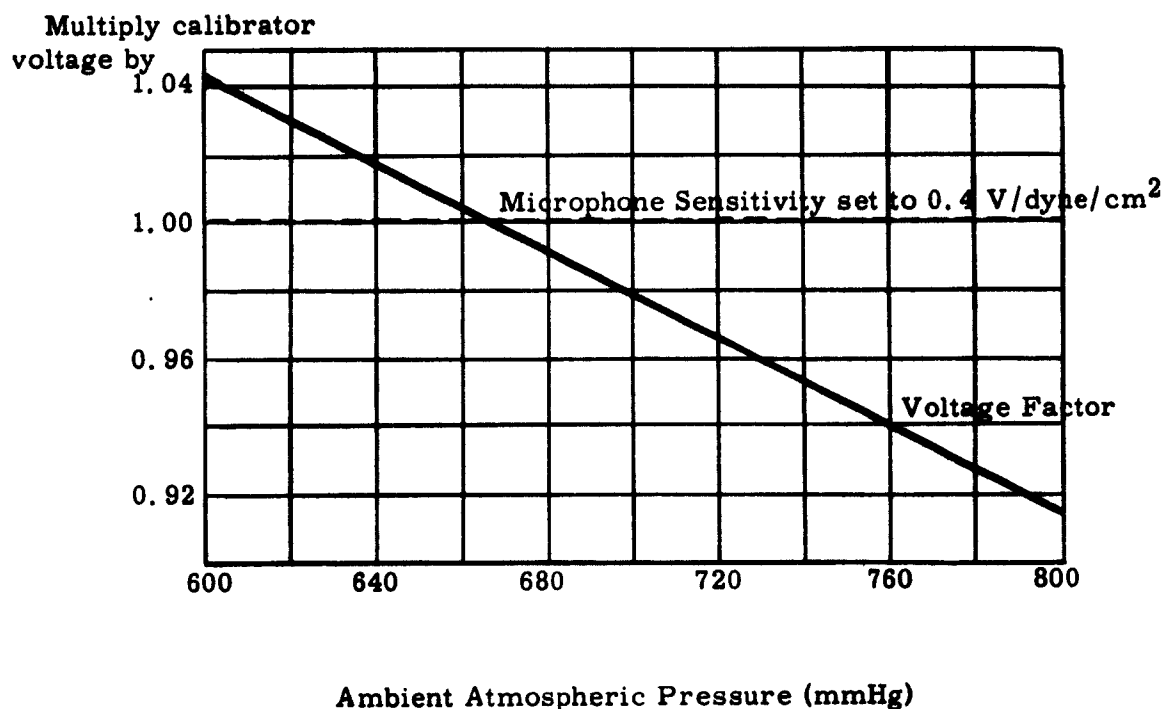
CALIBRATOR VOLTAGE FACTOR (for 0.4 volts/dyne/cm^2 sensitivity)

Figure 3-7

In designing a calibrator for use at field stations we have tried
to keep the following criteria in mind:

    a. Dependability and consistency - accuracy ± 5%

        (1) From one microphone to another;

        (2) Under varying local conditions of pressure, temperature
            and humidity.

    b. Economy

    c. Ease of operation

d. Portability

The calibrator reliability from microphone to microphone is quite good as stated in the June report. Its accuracy under a range of local conditions is also acceptable. The calibrator is easily manufactured from inexpensive materials, and it is certainly portable.

In considering its ease of operation, the calibrator was originally designed to be used with a minimum of equipment--a small audio oscillator and a VTVM, and as a bench calibration. Although the oscillator and VTVM could be used at the ends of the microphone array, to do so would be inconvenient. We are attempting to build a compact, inexpensive oscillator powered by batteries to supply the calibrator. With this accessory, microphones could be calibrated at the array without disconnecting them.

In general then, the present calibrator appears to be a highly satisfactory device for calibrating microphones in the field. Of course, each calibrator built will receive complete testing in each of the previously mentioned areas before it is sent into the field. A manual on the use and characteristics of the calibrator is also planned.

SECTION IV

PORTABLE PISTONPHONE

IV. PORTABLE PISTONPHONE

1. General Description

This pistonphone is intended primarily to determine the low-frequency response of the SRL Model 2 capacitor microphone. With reservations, other microphones can be tested. Amplitude calibrations can be made with moderate accuracy (5 to 10% on Model 2). The design goal was compactness and light weight (compared to other pistonphones), and, by accepting other limitations, this was possible. The pistonphone can be assembled and used on most any sturdy table or bench (Figure 4-1).

There are two frequency ranges:

High range   --   1 cps to 30 cps

Low range   --   0.25 cps to 9 cps

The Frequency Control varies the speed of the motor in each range. The range can be selected from the two output connectors on the back panel. The pressure amplitude can be changed by changing the stroke length of the piston. Two tapped holes are provided in the piston flywheel for the crankscrew. The pressures are 24.6 dynes/cm^2 peak-to-peak and 30.9 dynes/cm^2 peak-to-peak. The distortion is generally less than 7% on the short stroke and 10% on the long stroke. The distortion measurement necessarily includes the distortion of the microphone

FIGURE 4-1
PORTABLE PISTONPHONE & SRL CAPACITOR MICROPHONE

The portable pistonphone is shown in a typical test setup
with the SRL Capacitor Microphone and Power Supply
(behind microphone) connected for test just prior to
placement of the microphone in the test chamber of the
pistonphone.

and extraneous background noise because of the type of distortion analyzer used (H. P. 1330D). Figure 4-2 compares the frequency response of an SRL Model 2 microphone in the SRL NASA pistonphone and in the portable pistonphone under present discussion. The box weighs 28 pounds and the control unit weighs 17 pounds. Power requirements are 110 VAC, 60 cps, at 3 amps maximum.

2. Operation

The portable pistonphone can be set up in any place where there is sufficient work room and where it will not be subjected to severe shock or vibration. The A. C. power requirements are not critical unless long-term measurements at one frequency are desired. Then some sort of line voltage regulator would be required, since the motor speed is a function of the applied voltage.

The flexible shaft should be connected to the piston assembly on top of the pistonphone and to the appropriate output on the back of the control panel. The piston flywheel might have to rocked gently by hand to allow the cable to enter the connector smoothly. The shaft should not have any sharp bends, say a minimum radius of 6 inches.

The microphone to be tested should be placed in the chamber and connected to the cable. This cable will directly fit SRL Model 2 micro-phones, but can be adapted to others. When the door is closed and seated firmly against the gaskets, all four spring snaps must be clamped to

Amplitude Volts (p-p)

15.43 dynes/cm^2 rms NASA Pistonphone

30.9 dynes/cm^2 p-p Long Stroke Portable Pistonphone

24.6 dynes/cm^2 p-p Short Stroke Portable Pistonphone

frequency (cps)
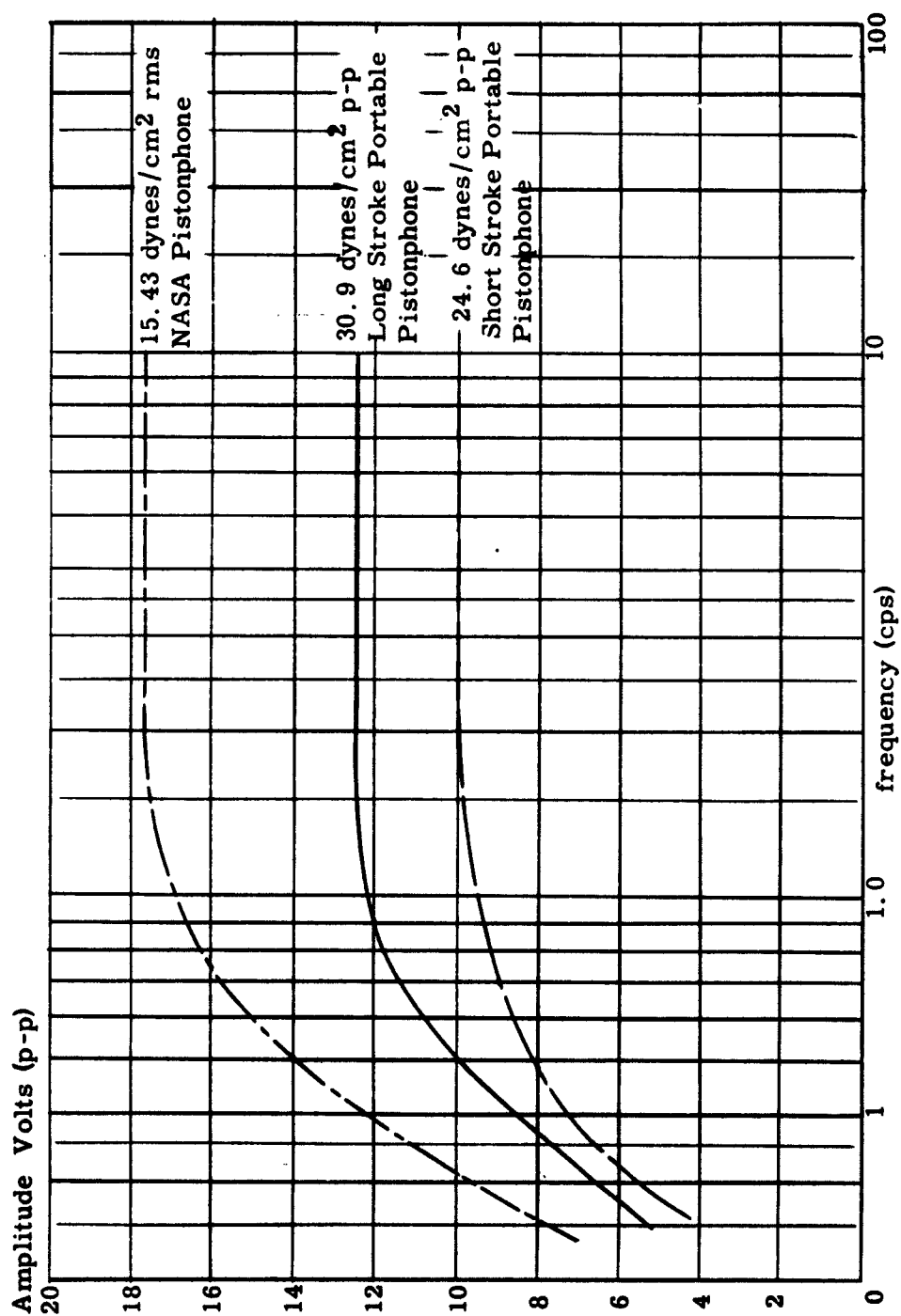
Figure 4-2

obtain a good air seal. A military type sealed connector (AN 3102 C) is used to get the cable through the wall of the box. The cable going to the capacitor microphone power supply is fastened to this connector.

The determination of piston frequency can be made from the time base of the monitoring instrument (oscilloscope or strip chart recorder). No markings are on the frequency control dial, since the speed is dependant upon line voltage. A waxed pencil can be used to place reference marks on the plastic dial. For a steady state test, the frequency control can be set to any position and readings taken. For a decreasing frequency sweep, the frequency control can be set to maximum; when the piston reaches top speed, the power is cut off and the piston coasts to a stop. Some electrical noise from the motor brushes is eliminated by this method.

3. Construction Details

The box is constructed of two layers of 3/4-inch plywood on all sides to obtain as much rigidity as possible. Initially, air leaks were a problem, and various wood sealants were tried. Finally, fiberglass resin was used and it gave the best results. A large size of sponge rubber weather stripping is used for the door. A double gasket system is used, thereby giving an acceptable leak rate. The aluminum covering is primarily to provide electrical shielding and a banana post is provided for connection to this shield.

In the original model, the motor and speed reduction pulley were mounted on the top of the box. This caused vibrations that even the 1/2-inch aluminum piston assembly mounting plate could not isolate. A separate box, housing the motor and reduction pulley, stopped this source of noise. A schematic is shown in Figure 4-3.
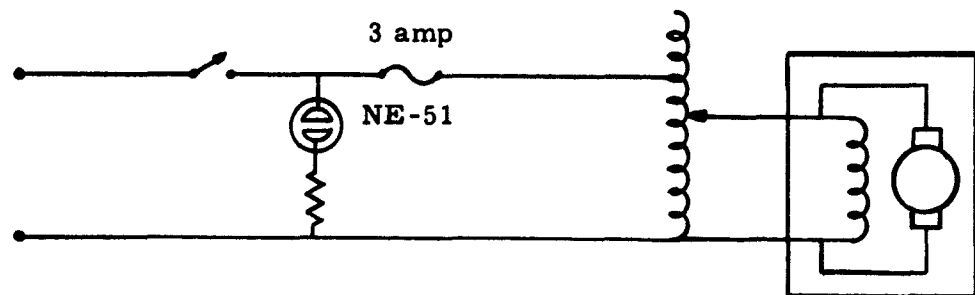
Figure 4-3

The drive to the piston is by ordinary automotive speedometer cable. The piston and cylinder are from a model airplane engine. They are lapped to each other to a very close tolerance and, if sufficiently lubricated, wear should be no problem at the speeds and temperature used. In model engine service, they are good for many hours of service at temperatures in excess of 100°C and at speeds higher than 15,000 rpm. The piston drive shaft is mounted in ball bearings and a minimal flywheel is used. The piston-flywheel assembly is placed on a block of wood to provide additional mechanical isolation. The small internal size of the box permits standing waves

and resonant frequencies. The glass wool padding on four walls suf-
ficiently damped these waves. However, the padding hinders an exact
calculation of the volume and, hence, the pressure of the pistonphone.

4. Pressure Calculations

In a pistonphone, the change in pressure is given by:

$$p = \gamma P \frac{\Delta V}{V} ,$$

where p = sound pressure (p-p)

γ = ratio of specific heats

P = atmospheric pressure

ΔV = piston change in volume

V = volume of chamber .

At 660 mm Hg and 20°C

$$P = (1.01325 \times 10^6) \frac{660}{760} = 8.7993 \times 10^5 \text{ dynes/cm}^2$$

and

$$P = 1.2334 \times 10^6 \text{ dynes/cm}^2 .$$

Calculation of the sound pressure from measurements of the box is
complicated by the accuracy of measurement and by the indefinite
volume of the glass wool. These calculations are included as a com-
parison only; the amount of pressure is in actuality determined by
comparison with the SRL NASA pistonphone given under "General
Description."

Base = 0.526 in

Short Stroke = 0.164 in

Long Stroke = 0.200 in

Displacement volume = 584 mm^3 and 714 mm^3

Volume of chamber = 2.76 x 10^7 mm^3 (1683 in^3)

Sound pressures by volume measurement = 26.1 and 31.8 dynes/cm^2 p-p.

The volumes of the microphone and the compressed glass wool are $\simeq$ 70 in^3 and 36 in^3, respectively. They would tend to make the calculated sound pressure slightly larger. The response of almost any small microphone may be tested, but the absolute sound level of the pistonphone would have to be modified due to the different microphone volume.

Figures 4-4 and 4-5 show the sound pressure of the two stroke lengths at various atmospheric pressures.

Figure 4-4

Portable Pistonphone
Output Variations with
Atmospheric Pressure
Changes - Short Stroke

FIGURE 4-5

Portable Pistonphone
Output Variations with
Atmospheric Press-
ure Changes
Long   Stroke

Atmospheric Pressure (mm Hg)

Pistonphone Output (dynes/cm^2) rms
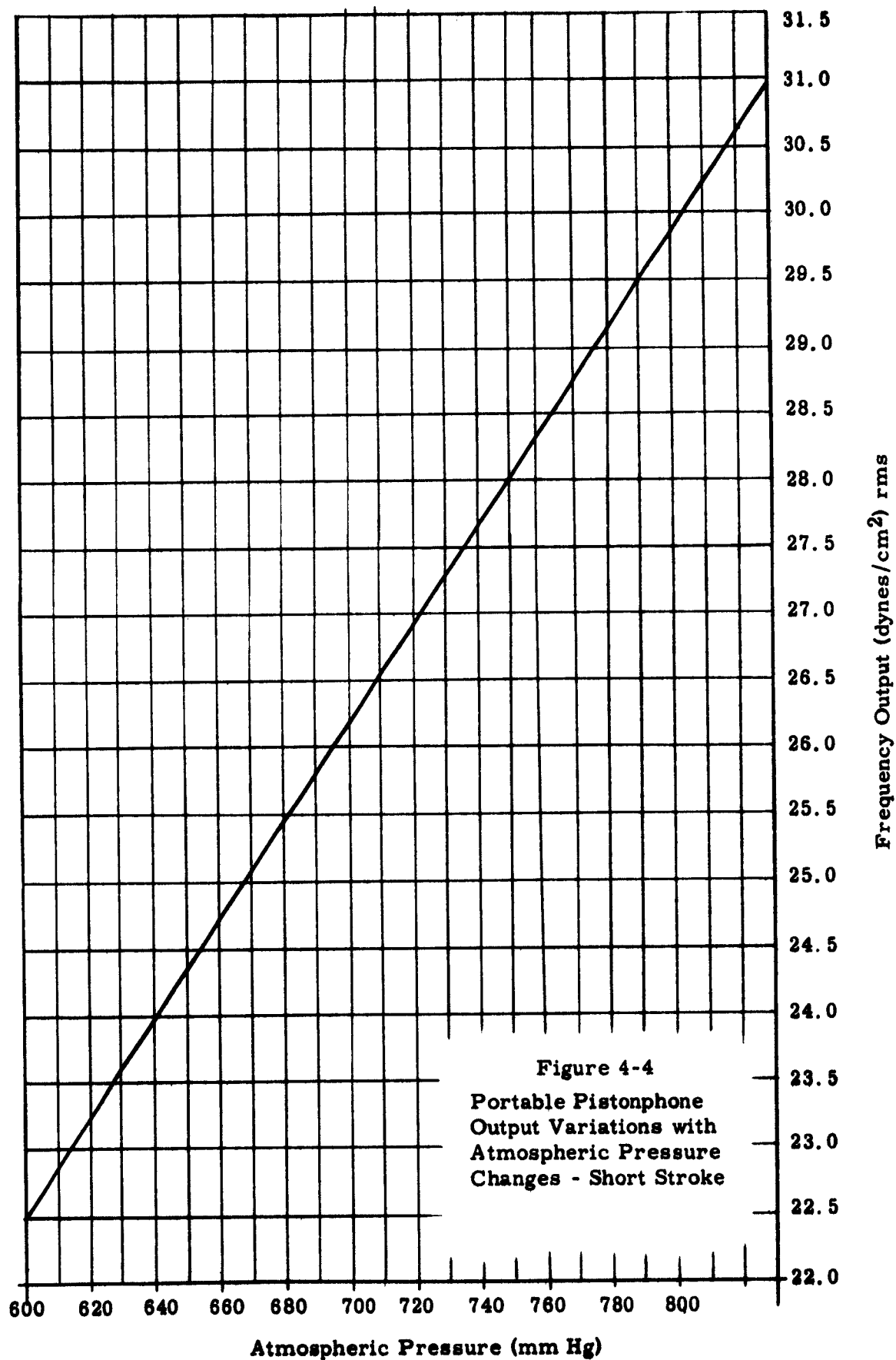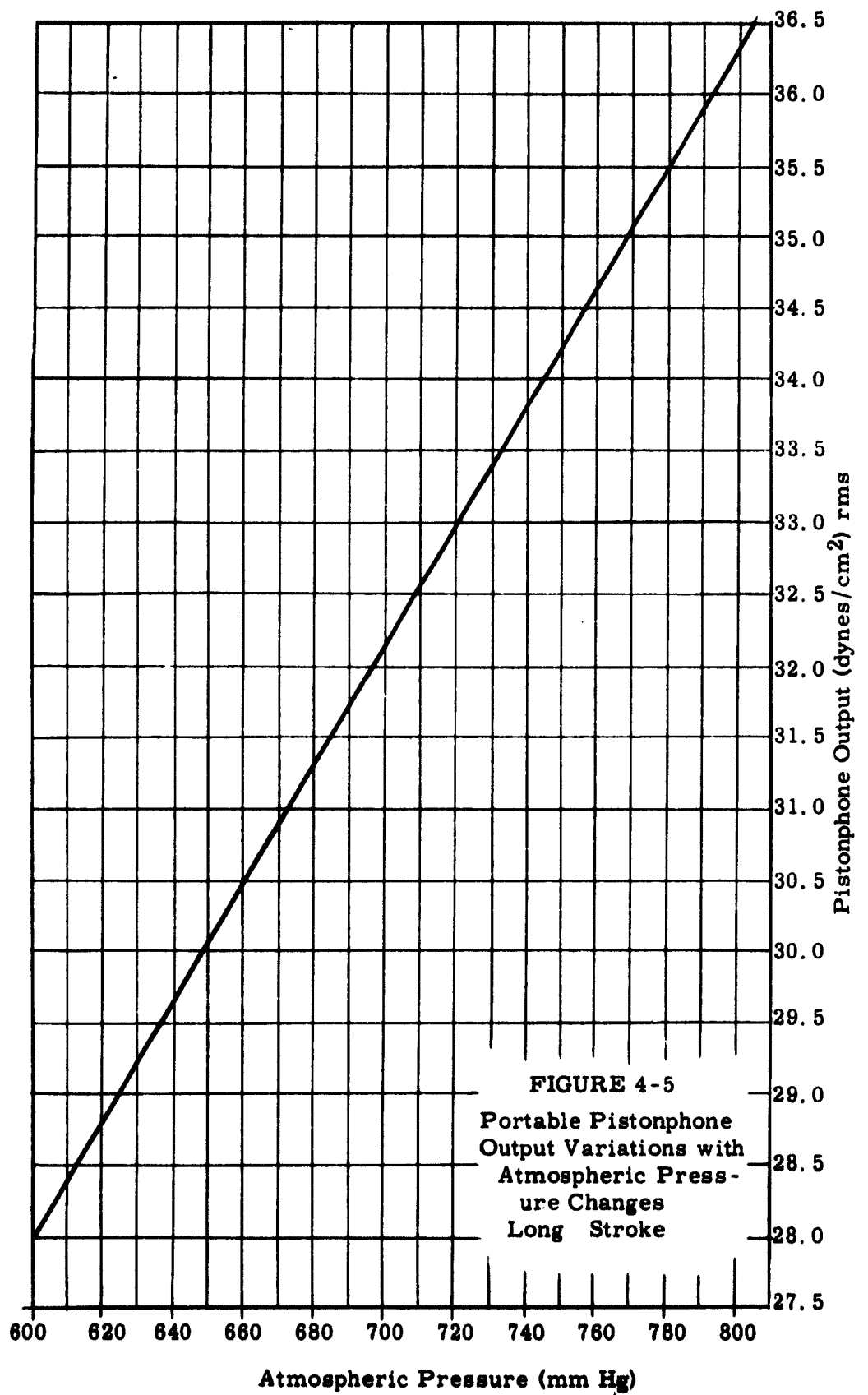
SECTION V

MARK III MICROBAROGRAPH

V. MARK III MICROBAROGRAPH

1. Pressure Response

This is a description of the determination of the pressure response of the Mark III microbarograph. The output for various pressures was needed to confirm the linearity of the response. The equipment was set up as shown in Figure 5-1. The bridge was balanced as described in the instruction manual.[1] No acoustic filter was available. The 100 db calibration box is normally used for rough setting of the gain on the capacitor microphone; it was used in this case to provide the same signal to the reference microphone and the microbarograph. The box has a permanent magnet speaker for a driving source. This provided the most flexible testing scheme available. It was driven at such a level and loaded by the box so that a very good sine wave was produced. Five cps was chosen as the pressure rate and was used for all levels. The sensitivity obtained compared favorably with that found by Rios.[2]

Distortion does not show on the microbarograph until 38 dynes/cm^2 is reached. At this level the attenuator switch on the capacitor microphone was changed to the 100 db position. The microbarograph

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[1] Extract of Mark III Equipment Instruction Manual, U.S. Army Signal Operations Agency, Fort Monmouth, New Jersey.

[2] Rios, R., Microbarograph Frequency Responses and Sensitivity Report, Quarterly Status Report, Schellenger Research Laboratories, April-June, 1961, Contract DA 29-040-ORD-2410.
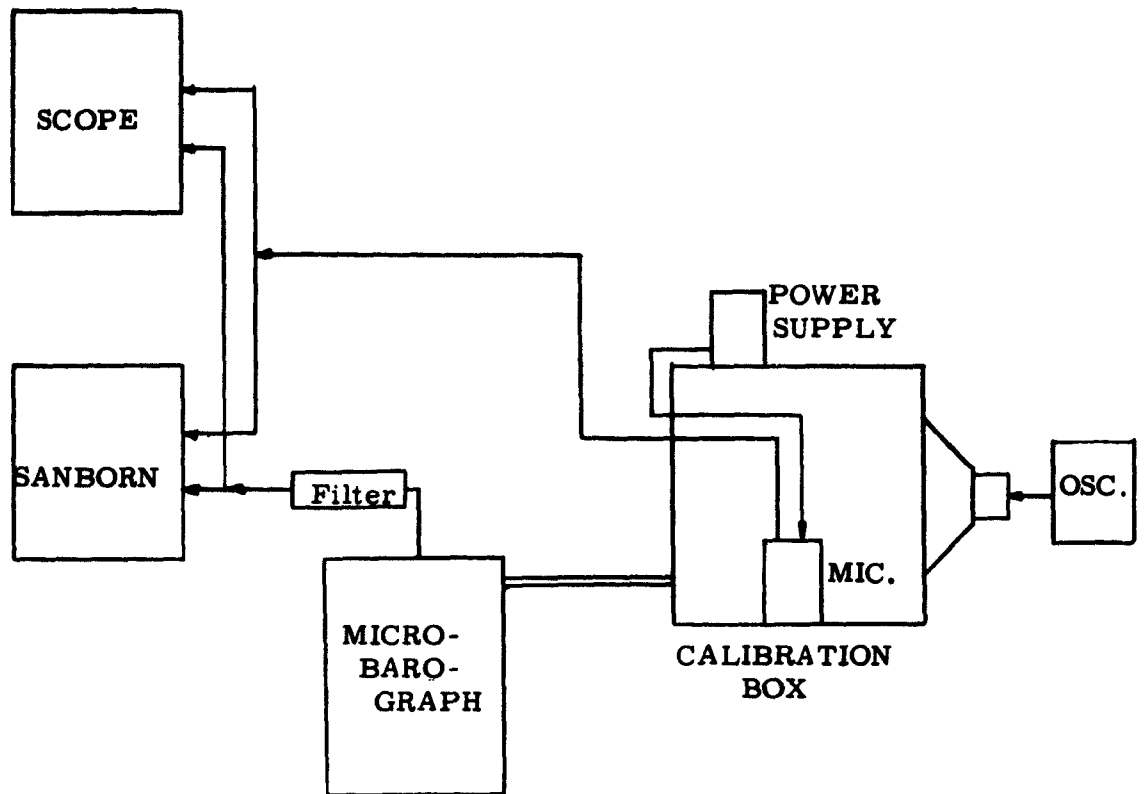
Figure 5-1

TEST SET-UP FOR DETERMINING
PRESSURE RESPONSE OF THE
MICROBAROGRAPH

was operated in the 9 db position at all times.

It is known that at higher frequencies the capacitor microphone is linear; (the G.R. microphone can be used at, say, 50 cps) and there is no reason for doubting the linearity at lower frequencies. From the graph (Figure 5-2) it can be seen that the microbarograph is nearly linear, especially when the wide range of pressure is considered.

Pressure Response of Microbarograph

DATA

Test Frequency: 5 cps

	Capacitor Microphone (volts p-p)	Microbarograph (volts p-p)	Pressure (dynes/cm^2) rms
1.	23	5.0	25.8
2.	14	3.2	15.7
3.	7.6	2.0	8.5
4.	3.5	0.7	3.9
5.	2.1	0.53	2.4
6.	34	6.5	38
7.*	1.9	6.5	38
8.**	3.4	9.0	68
9.	5.0	11.0	100

NOTES:

* Capacitor Microphone changed to position 2.

** There was noticeable distortion by the microbarograph from this point on.

FIGURE 5-2
PRESSURE RESPONSE
of
MICROBAROGRAPH
SRL Capacitor Microphone
used as reference.

March 28, 1962   LLC
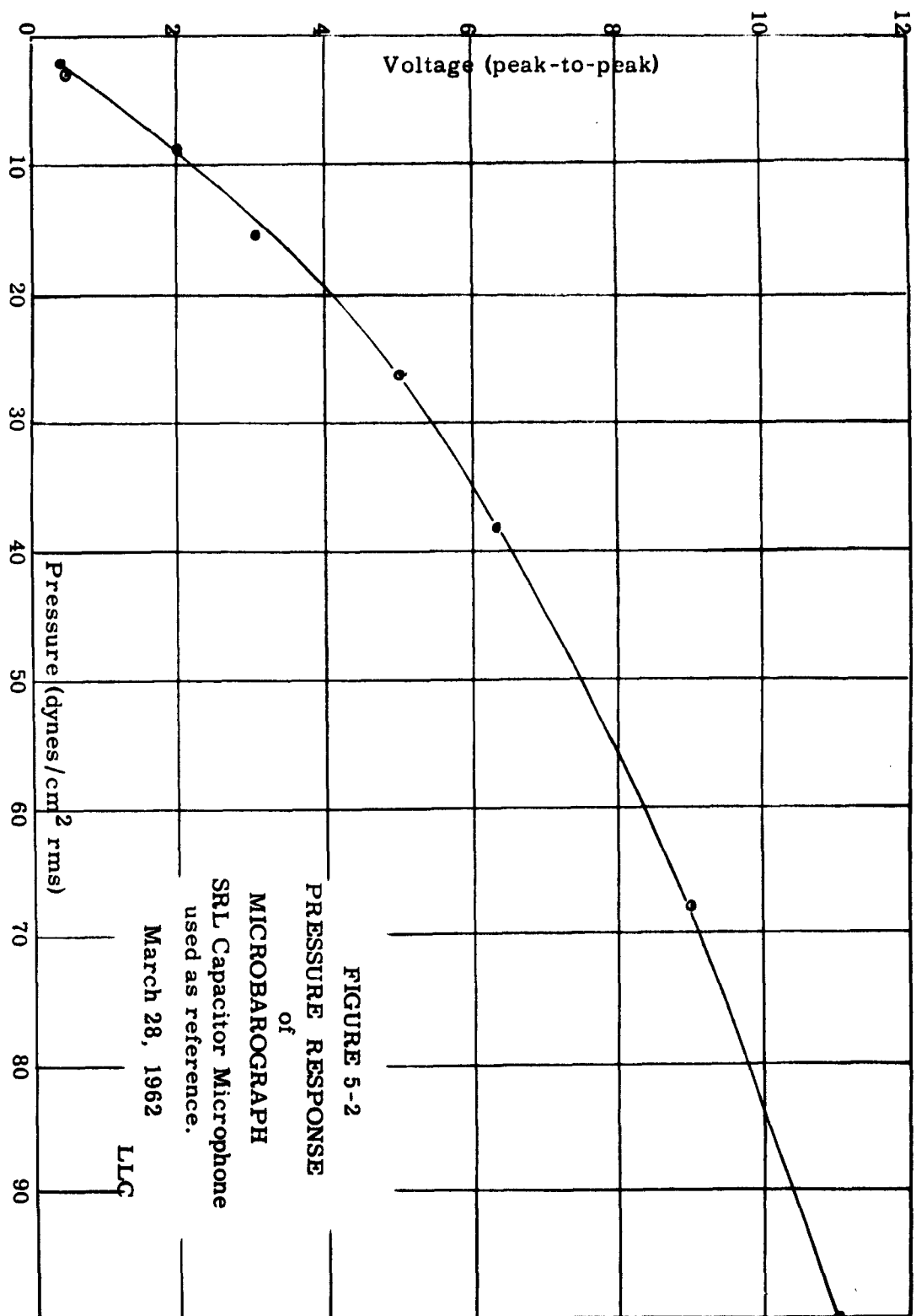
2. New Pistonphone Microbarograph Tests

The new pistonphone that SRL is constructing for a NASA program is in the final testing stage. It has output pressures of: 1.5, 16, 58, and 160 dynes/cm^2, the current frequency band extends from 0.006 cps to 32 cps, and the size permits testing of fairly large systems (door opening: 2 ft. in diameter, length of chamber: 42 inches). Incidental to testing the pistonphone, a response curve was run on a microbarograph and a Model 2 capacitor microphone (Figure 5-3). The output of the pistonphone should be flat to below 0.01 cps and even the isothermal - adiabatic changeover should be below this frequency.

3. Sound Ranging Tests

Under a NASA contract, Schellenger Laboratories is providing a sound ranging station at Eglin AFB. This station is listening to the high altitude grenades of the Firefly program. SRL's interest is to determine the characteristics of the sound arrivals and their effect on the microphones.

Two microphone sites have been chosen. The first is in dense, tropical foliage and the second is relatively open. Both sites have wind screens and pits similar to those at the Wallops Island sound ranging station. Microphone types are: 1. SRL Hot Wire system; 2. SRL Capacitor system; and 3. Microbarograph with an open air inlet. (It was not feasible to transport the pipe filter.)

Figure 5-3
Microphone
... cps/cm³

Model 2
Microphone

Microbarograph

Decibels

Frequency (cps)
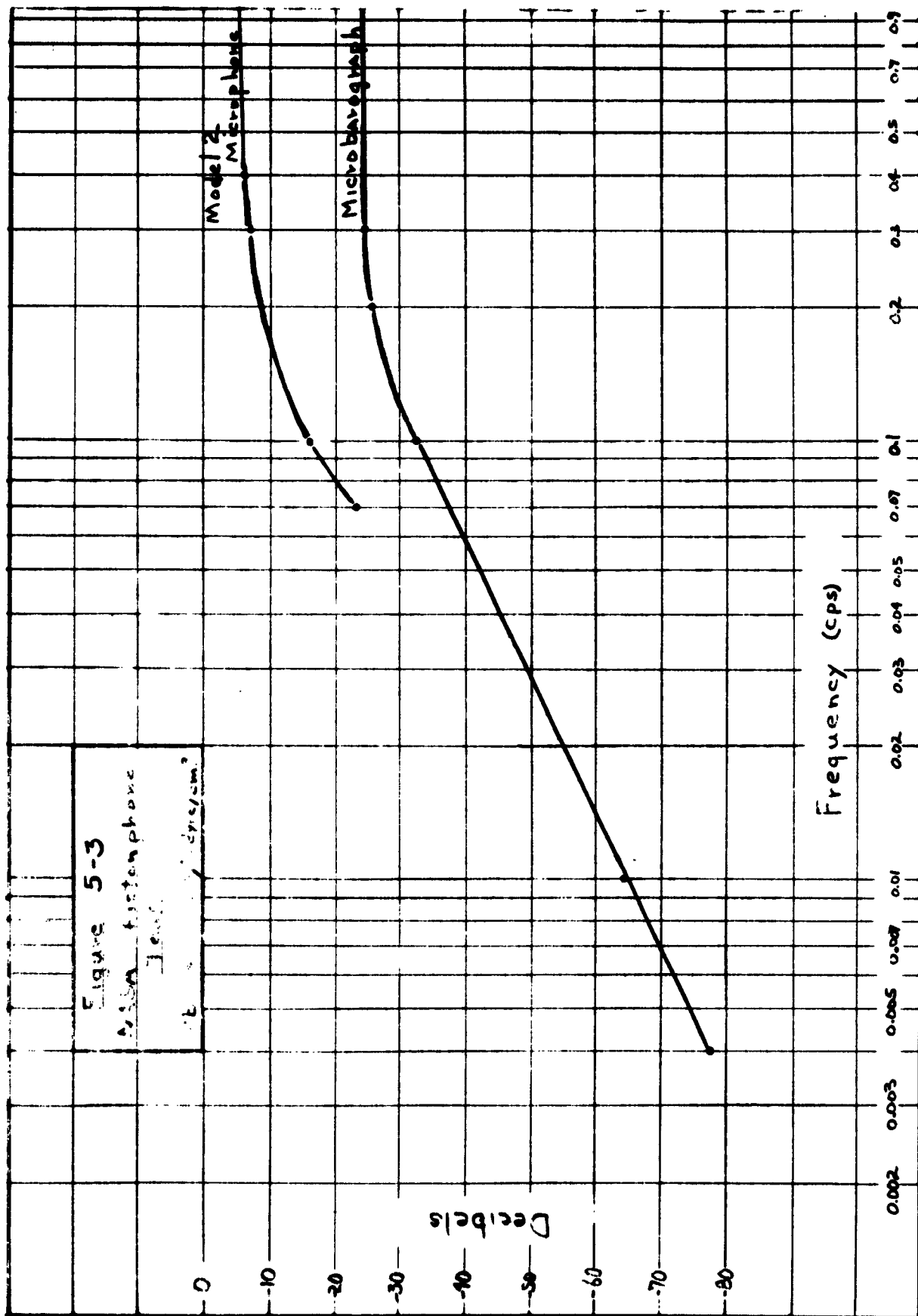
On one experiment, grenades were fired at altitudes of 90, 96, 102, and 106 km. All microphones received all sound arrivals. Signal-to-noise measurements (disregarding microphone bandwidth) show that the microbarograph and the capacitor microphone are approximately the same. The hot wire microphone was tuned to receive signals from the 90 km. region (4 cps) and on this experiment shows a better ratio on the first two grenades. However, as the altitude of the grenade rises, the ratio for the hot wire rapidly falls off to a value less than the other two. Figure 5-4 shows the shape of the arrival signal.

4. Microbarograph Phase Shift

The microbarograph phase shift graph in Figure 5-5 was obtained with a pistonphone arrangement described in the December monthly report. A sound pressure of 98 db was used. The microbarograph equipment included the passive filter network normally used with this instrument and no acoustic input filter. The amplitude of the micro-barograph signal was approximately flat from 1 cycle to 9 cycles. Tests were made for phase shift with the microbarograph balanced at the 12, 27, and 39 db attenuator settings. Distortion of the waveform was evident at the 12 db setting.

The readings taken were within ± 5° of the line plotted. The attenuator settings and the balancing of the bridge both appeared to affect the phase shift slightly. Generally the signal with the attenuator
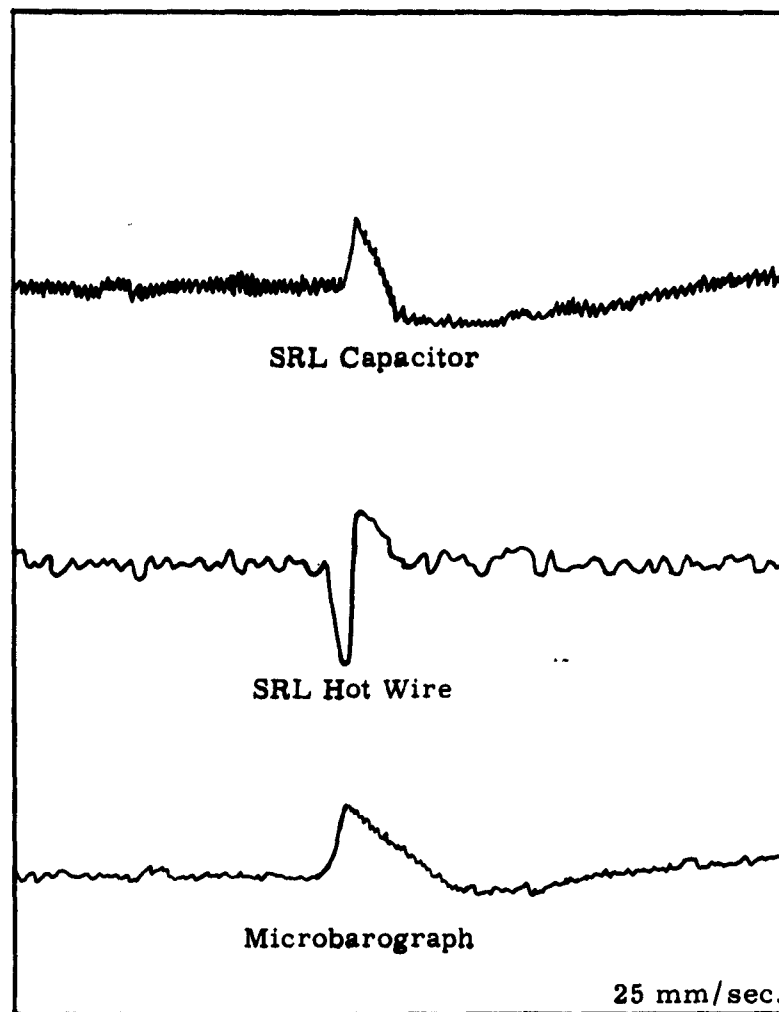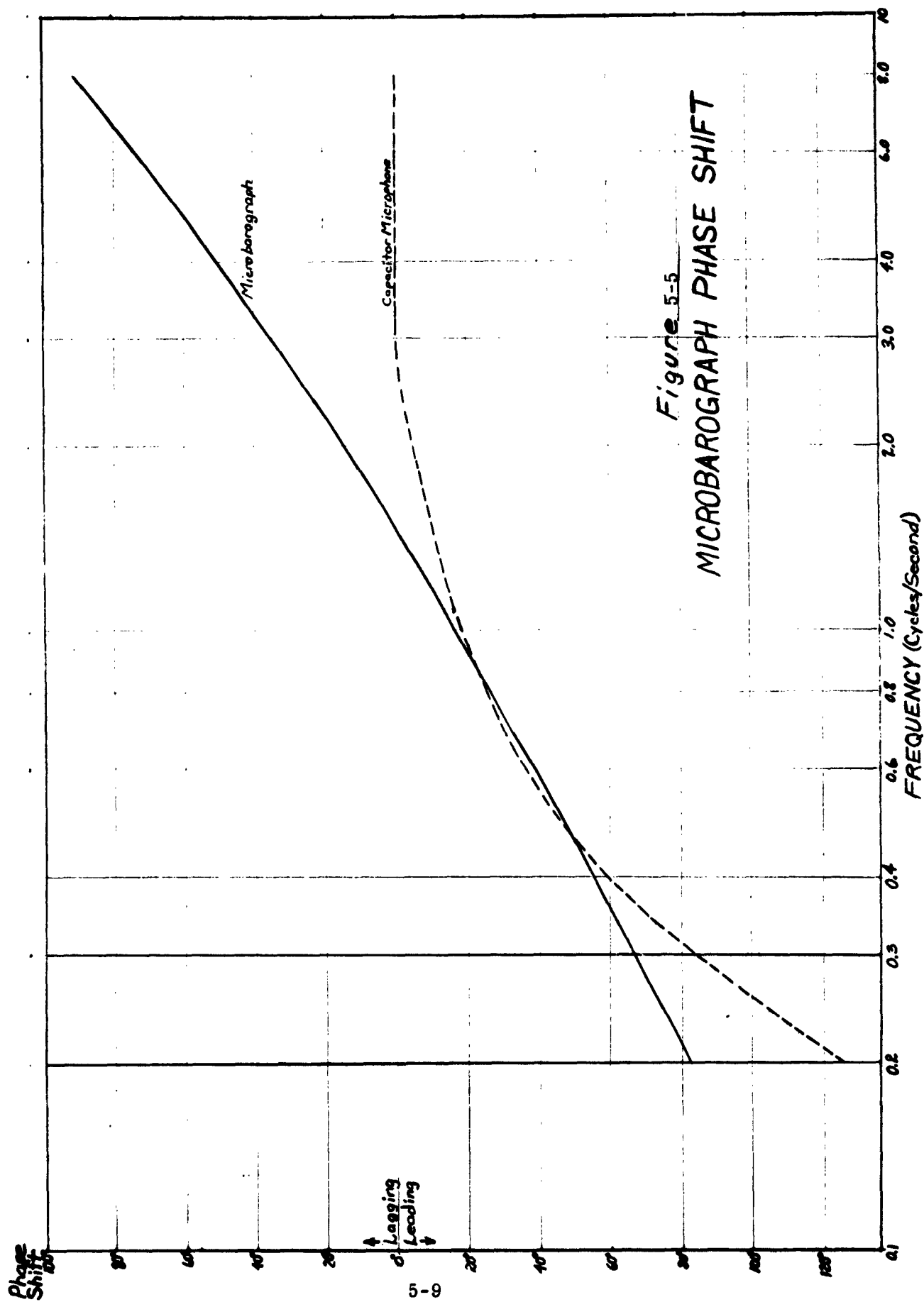
Figure 5-4
Sound arrival from 95.7 km. Each signal amplified to
produce the same peak amplitude.

Figure 5-5
MICROBAROGRAPH PHASE SHIFT

FREQUENCY (Cycles/Second)

set in the 27 db position lagged the signal of the 39 db position by about 5°. With the bridge purposely unbalanced (27 db position) to cause a 2 db decrease in signal amplitude, an additional 4° leading phase shift was noted. It may be noted that <u>both</u> figures are <u>less</u> than the general deviation of individual points from the curve. They serve, then, only as an indication of trend and order of magnitude.

5. <u>Transient Response</u>

Tests were conducted on the SRL capacitor microphone and on the microbarograph to determine their response to a near step-function pressure input. The NASA pistonphone was modified to allow movement of its piston rapidly from a position most of the way out to a position all the way in. Simultaneous recordings were made of the pressure variation indication and the responses of the microphone and the microbarograph. The pressure variation indication was obtained by attaching a potentiometer and battery to the rotating shaft of the pistonphone. Since the time constant of the pistonphone is about four hours, the pressure input does not leak out appreciably during the period of one test.

The tests (Figure 5-6) showed two interesting results:

a. There is a lag time between the break times of signal input and the microbarograph output; negligible lag time in the capacitor microphone.

b. Both instrument outputs swing negative after their positive excursions.

MICROBAROGRAPH 0.02 VOLTS/MM

CAPACITOR MICROPHONE 0.5 VOLTS/MM

100 MM/SEC.

PRESSURE INDICATION

TRANSIENT RESPONSE
FIGURE 5-6

5-11
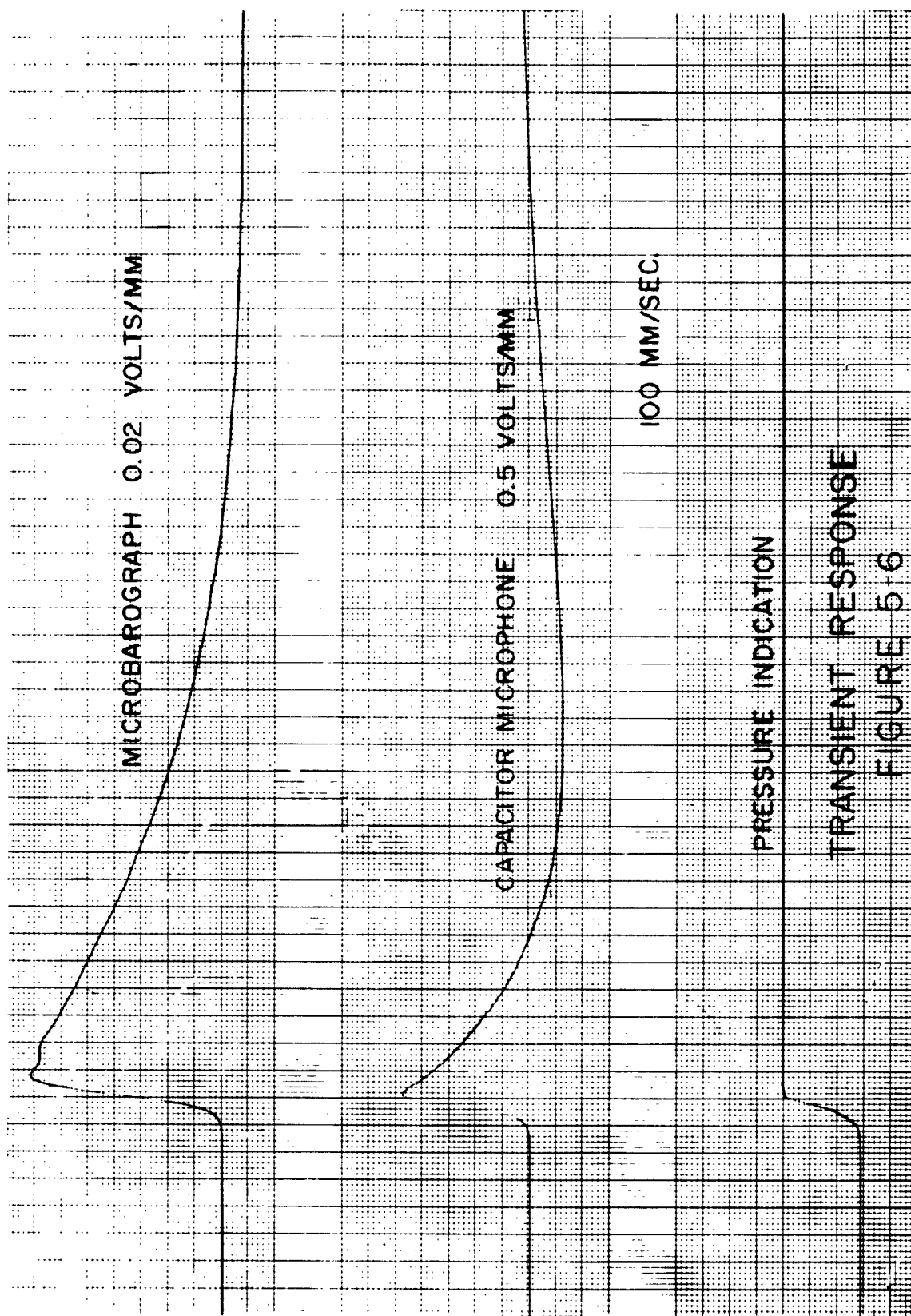
Both the microphone and the microbarograph do not deviate greatly from the input wave. However, the response of the microbarograph is delayed by about 30 milliseconds. The delay showed up consistently over several dozen tests. The delay, if any, in the capacitor microphone was not detectable by the above methods. This delay time would be of paramount importance in sound ranging.

The capacitor microphone swings negative at about 0.35 seconds after the beginning of the pulse. The microbarograph takes about 1.15 seconds. The capacitor goes negative about 1/4 as much as it went positive originally; the microbarograph only about 1/10.

Note that the plot for the pressure indication in Figure 1 is not a direct indication. About 8° of shaft rotation is represented by 1 mm, but the shaft rotation is translated to sinusoidal piston movement by a scotch yoke. Physical positioning starts the pulse at -42° and ends at +90°. Such values were chosen so that at least the first 2/3 of the pulse would be represented with reasonable accuracy (sine curve from -45° to +45° somewhat linear). During the last 1/3 of the pulse, an abrupt stop of the shaft rotation is shown. The pressure increase does not stop quite so abruptly.

SECTION VI

PIPE ARRAY

VI. PIPE ARRAY

1. Pipe Array Response

During June and July, an effort was made to determine the response of the pipe array. One method of simulating the response in a small space consisted of one pipe head coupled to a capacitor microphone as in Figure 6-1. The volume between the filter head and the capacitor element was made approximately 1/100 of the volume of the pipe. Thus the ratio of the total orifice area to the enclosed volume was almost the same. Then the response should be about the same. The response thus obtained is shown in Figure 6-2.

Such a treatment still gives no information as far as phase shift or directivity of the pipe array. Therefore, attempts were made to construct a low-frequency sound source capable of producing fairly large signals. A siren-type apparatus was constructed which consisted of the sound source and a rotating disk that had three openings. As the disk rotated, the area of the openings varied sinusoidally. The siren was capable of producing a 1 dyne/cm^2, 1 cps signal at a distance of 20 feet from an air tank of 150 psi. Spurious noise was much too high. A more usable signal might be obtained with more pressure, a less restrictive outlet, and improved directivity.

One of the pipe arrays was picked up from White Sands and installed at the Schellenger Lab Test Center. A few experiments were conducted.
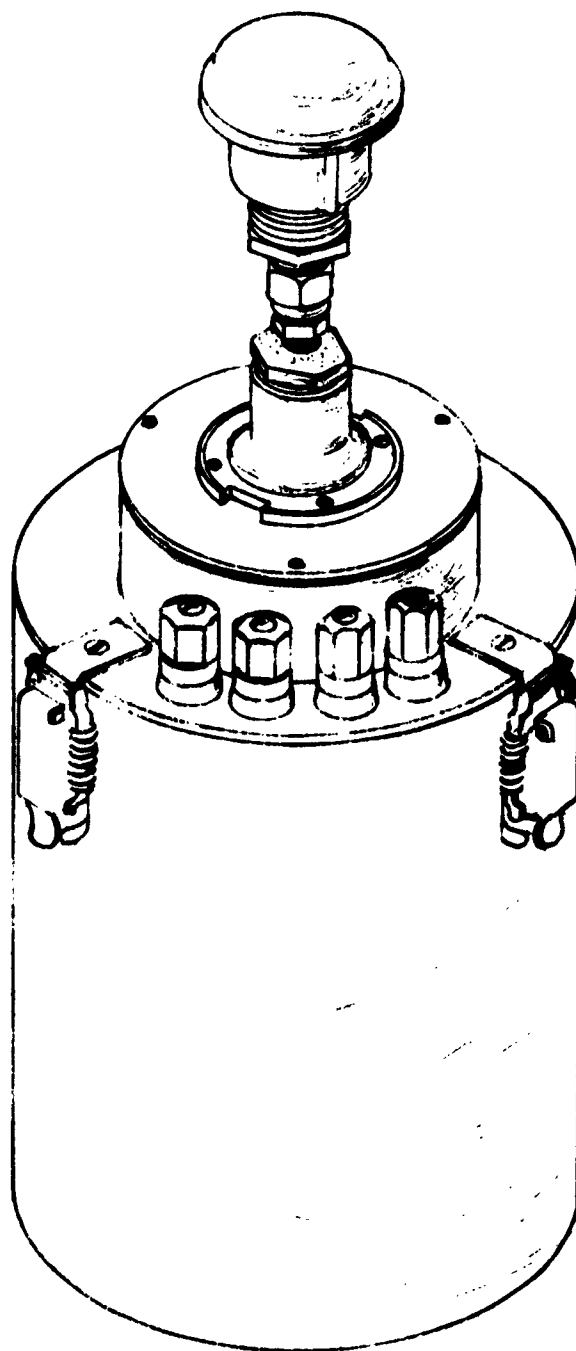
FIGURE 6-1

Method of Adapting Acoustical
Filter to Model 2 Microphone

Figure 6-2
Response of
Acoustical
Filter
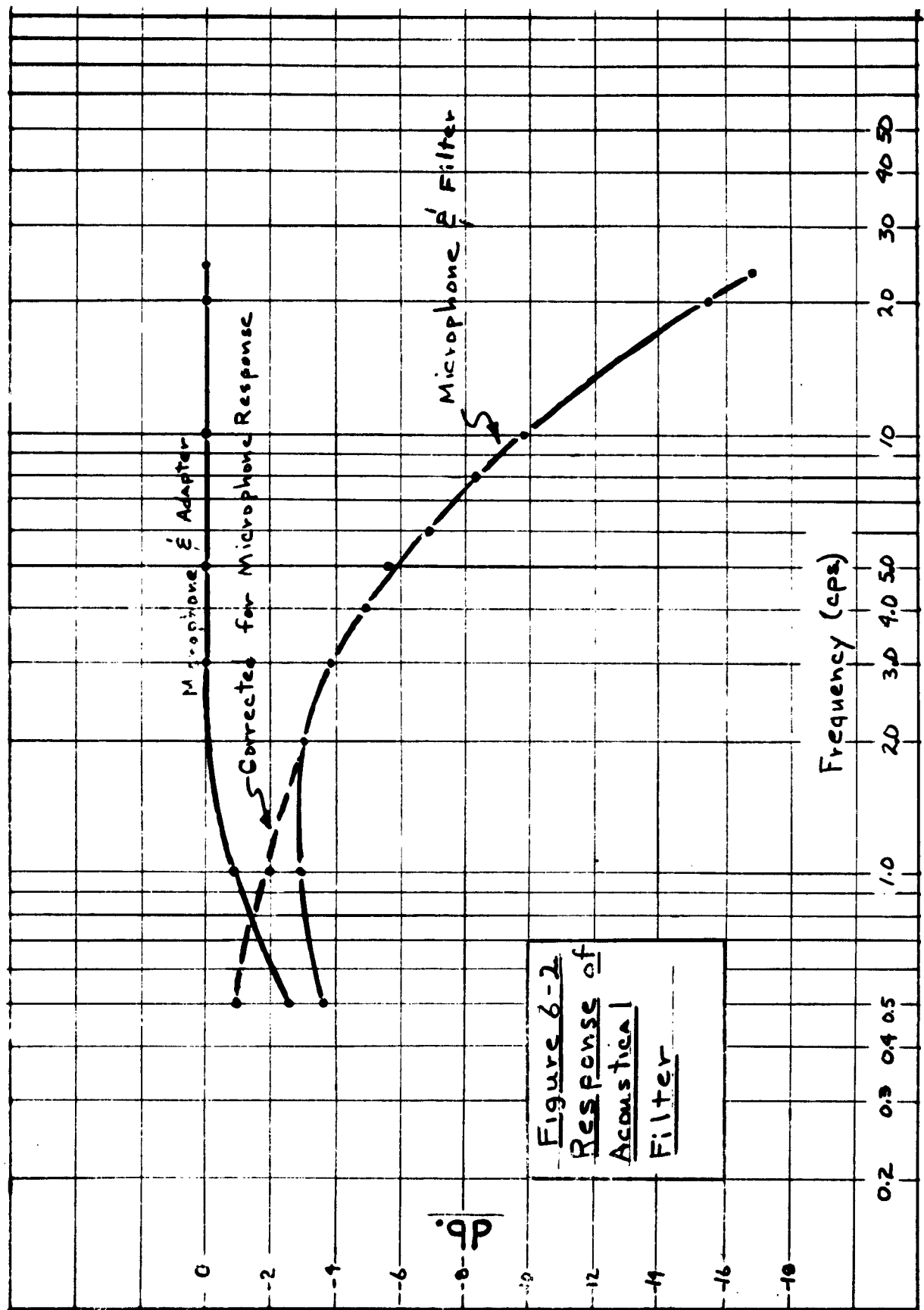
Preliminary study was also done on a method of coupling an acoustic signal to each of the inlets simultaneously.

2. Rain Shield Modification

During the installation of the pipe array from WSMR at the SRL Test Center, it was noted that a large amount of sand had collected in the pipe head. It was also noted that the sand screen inside the head proved ineffective due to its position. Sand reaching it merely filtered around its side. The personnel at WSMR stated that proper operation of the array required tedious cleaning of each head after a sandstorm. Unfortunately, such sandstorms are frequent at the missile range.

To solve the sand problem in this area, a screen was designed to fit on the head in a better position. The design, illustrated below, would eliminate all except very fine dust in the orifices. It would require a large number of stamped steel plates, nylon or brass screens, machining each head (part marked M), drilling and tapping two holes, and assembling.

Rain Shield Head

Figure 6-3
6-4
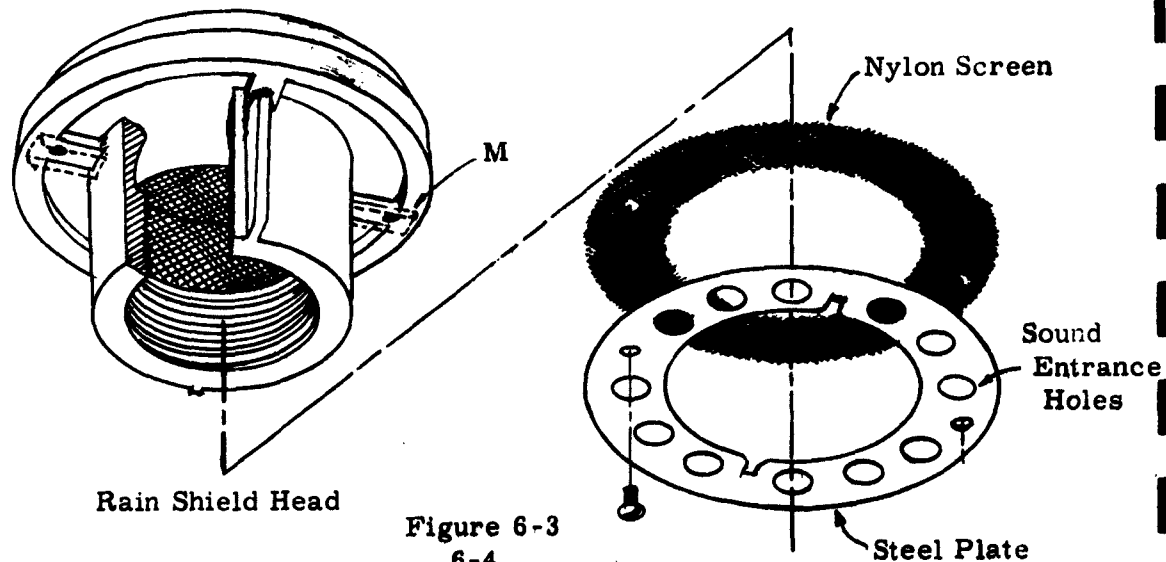
SECTION VII

ALTERNATE TRANSMISSION AND DETECTION SYSTEMS

VII.   ALTERNATE TRANSMISSION AND DETECTION SYSTEMS

1.   Pulse Modulation System

In an attempt to eliminate line noise problems a microphone was connected to modulate a blocking oscillator producing a pulse-period type of modulation (Figure 7-1). The system is insensitive to amplitude modulation since it is retriggered and clipped before integration at the detector. The basic frequency is 3000 pps, but this can be reduced some to get less line attenuation. A line attenuation of 26 db can now be tolerated in the working bench model. The present system needs a cathode follower added to match the line impedance before signal-to-noise and other measurements can be made. Also, the carrier pulse is still noticeable on the output of the detector. This system would be an answer for only the worst case of line noise because of the need for a rather expensive detector for each microphone and the decreased reliability because of the large number of added components.
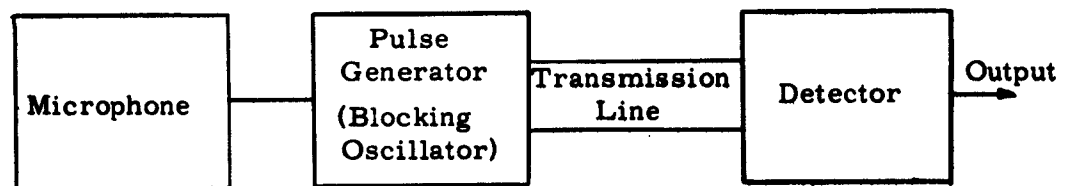
Microphone	Pulse Generator (Blocking Oscillator)	Transmission Line	Detector	Output

Figure 7-1
Block Diagram of a Pulse Modulation System
Applicable to Capacitor Microphone

7-1

2. FM System

Substantial preliminary investigation has also been made into an FM microphone system. A model was built using a capacitor microphone element in an oscillator, thus varying the frequency of a carrier. Only a moderate frequency change was noted. With this condition a very sensitive detector is necessary for proper operation at low sound-pressure levels. Several different detectors were tried but with little success. Due to the difficulty encountered in developing this system, efforts were shifted to other areas of more importance at the time.

3. Bridged "T" Detector

An RLC Bridged "T" capacitor microphone circuit was constructed in an effort to improve the low-frequency response. The capacitor microphone element backplate was split to form two capacitors of equal values. The two capacitors were wired into a bridged "T" as shown in the block diagram, Figure 7-2. The point at which the feedback is to be applied as a polarizing voltage on the two capacitor halves is low impedance to ground. This low impedance allows the output impedance of the balancing feedback amplifier to be reasonable, rather than the high impedance normally required for polarizing voltages on standard capacitor microphones. This circuit was quite sensitive to sound pressures. However, if a null is obtained, and the output signal is proportional

to the amplitude of the bridge output, the output frequency is double the input frequency. Thus the detection must be on the basis of phase-shift rather than amplitude. A phase detector insensitive to amplitude changes would be necessary to utilize the circuit's possibilities.
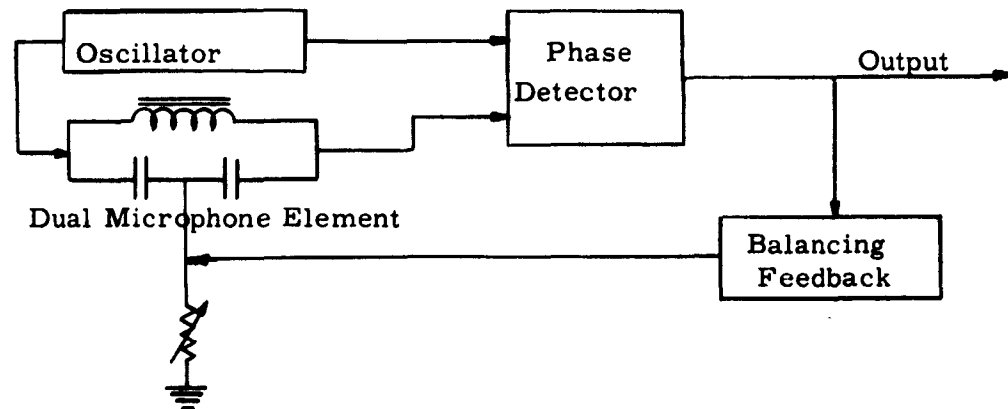
Figure 7-2
Self-Balancing Microphone System

4. Acoustically-Tuned Microphone

An acoustically-tuned microphone was constructed and tested. The inlet chamber is controlled by a series of interchangeable screws with small holes in their centers. The frequency response of several of these openings are shown in Figure 7-3. The back-up chamber was fitted with a similar device so that the low-frequency cutoff may also be varied. Figure 7-4 shows the inlet chamber, section view.

With this microphone, the response may easily be limited to any band of frequencies -- with an almost flat response for that band. A
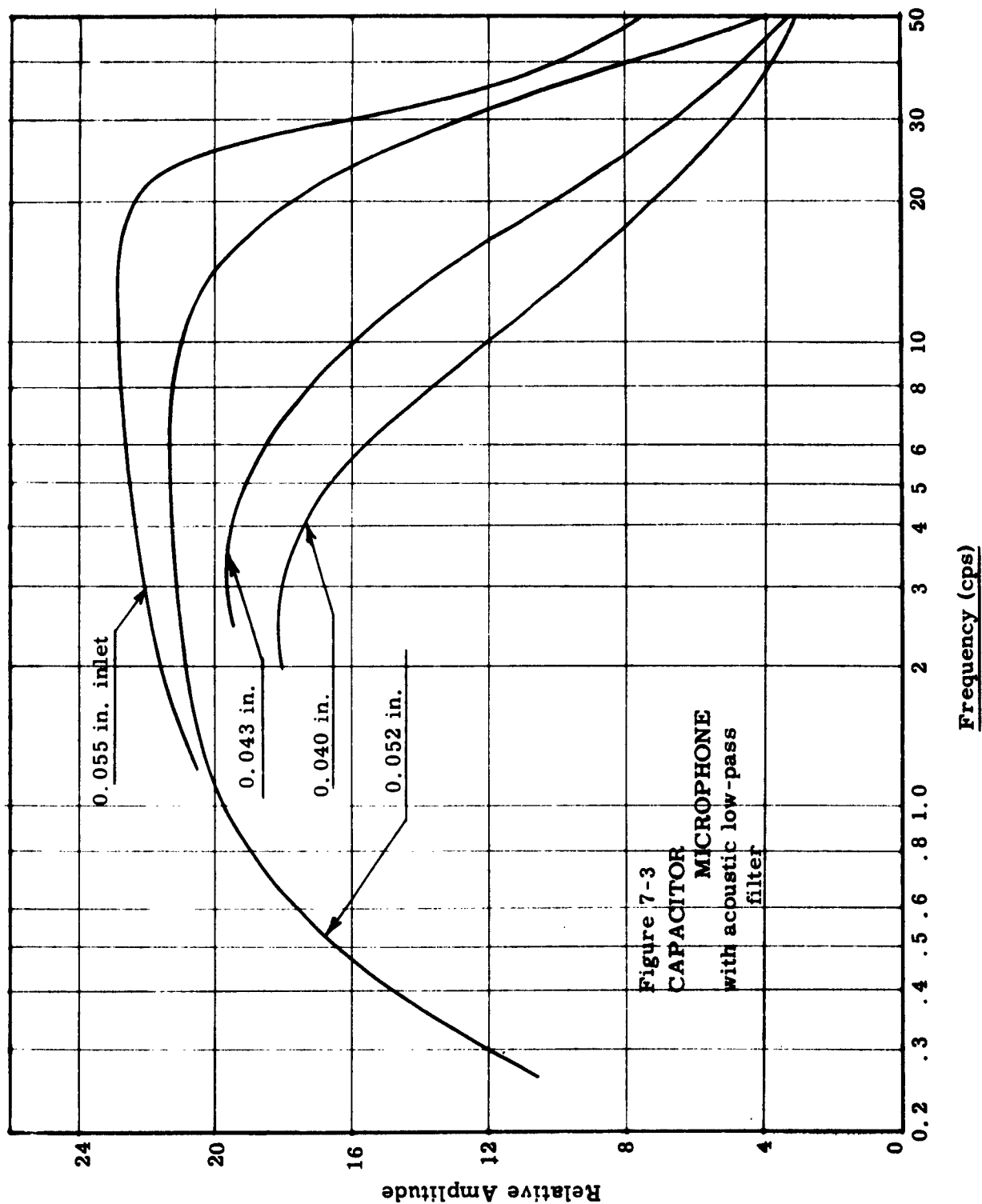
Figure 7-3
CAPACITOR MICROPHONE
with acoustic low-pass filter

0.055 in. inlet

0.043 in.

0.040 in.

0.052 in.

Relative Amplitude

Frequency (cps)

7-4
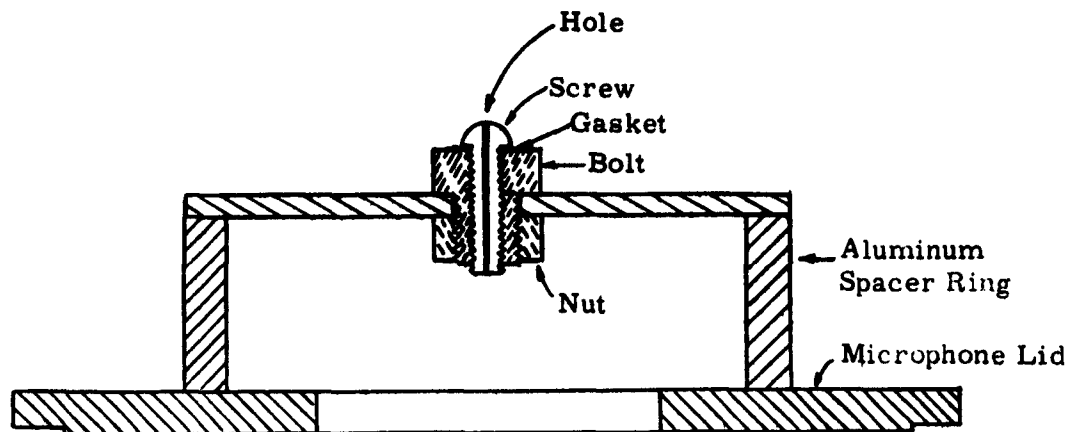
Figure 7-4
Tuned Microphone Lid

great deal of noise lying outside the bandwidth of the signal may be
eliminated by such a microphone resulting in a cleaner, more read-
able signal. Preliminary experiments were made using a tuned mi-
crophone and a pipe array. Such a comparison should show any
coloration of the signal by the method of coupling, such as resonances,
and an indication of the best way to get a good signal-to-noise ratio.

5. Hot-Wire Microphone

A similar narrow-band performance may be obtained from a mi-
crophone built at Schellenger for NASA. Possibilities exist for its
use in this project. The microphone is a vastly improved hot-wire
microphone designed to resonate at about 4.5 cycles. The sensitivity
of this microphone at its peak (about plus 2 db) is better than that of
the Ground Capacitor Microphone (-8 db). As may be seen from the

7-5

curve in Figure 7-5, the roll-off is about 6 db per octave, similar to what might be expected from a microphone with a controlled leak hole in both chambers.

SECTION VIII

FUTURE WORK

VIII. FUTURE WORK

1. General

During preliminary investigations into ways of getting better, more readable signals, it has been apparent (almost by definition) that a method for increasing the signal-to-noise ratio is essential. However, at the ultra-low-frequency range involved, little work can be done with present equipment in testing any system developed. Large output, outdoor test devices are in the audio frequency range or above, whereas the equipment under test is usually too large to be tested indoors because of the long wavelengths involved. Therefore the need for a large-output low-frequency sound source is essential in evaluating any system designed to increase the signal-to-noise ratio.

See Figure 8-1 for an outline of some of the methods considered. For a sound source perhaps the most promising method is some sort of internal combustion engine with the exhaust port almost open to the atmosphere through a low-pass filter pipe. Such a system should be able to be adapted to meet the desired requirements. One possibility for such an engine (although not readily portable) is an oil field pump engine. Those engines run at very slow speeds using a large flywheel. Since these engines are used in this area, testing will be facilitated.

The siren-type source still appears feasible but considerable work needs to be done to reduce spurious noise and increase outputs.

LOW-FREQUENCY SOUND SOURCE

10-20 dynes/cm^2 at 200 ft.

Frequency: 1-10 cps
Variable Frequency
Portable

PISTON TYPE

Large area and/or
long stroke
Sturdy baffle
necessary
Probably non-
portable
Near sine wave
produced

GAS RELEASE TYPE

SIREN TYPE (with
compressed air)

Needs high
pressure
Needs good seals
Good sine wave
possible
Probably not
portable
Much spurious
noise

CHEMICAL GAS
RELEASE TYPE
(Grenades, firearms)

Series of pulses
High output possible
Safety precautions
necessary
Frequency control
difficult
Portable

BURSTING DIAPHRAGM

(Balloon, etc.)

Single or series
of pulses
Medium output
Frequency control
difficult
Portable
Safe

INTERNAL COMBUSTION
ENGINE

Series of pulses
Portable
Variable frequency
Medium output
Safe

LOW-PASS FILTER

For smoothing pulses
into approximations
of sine waves
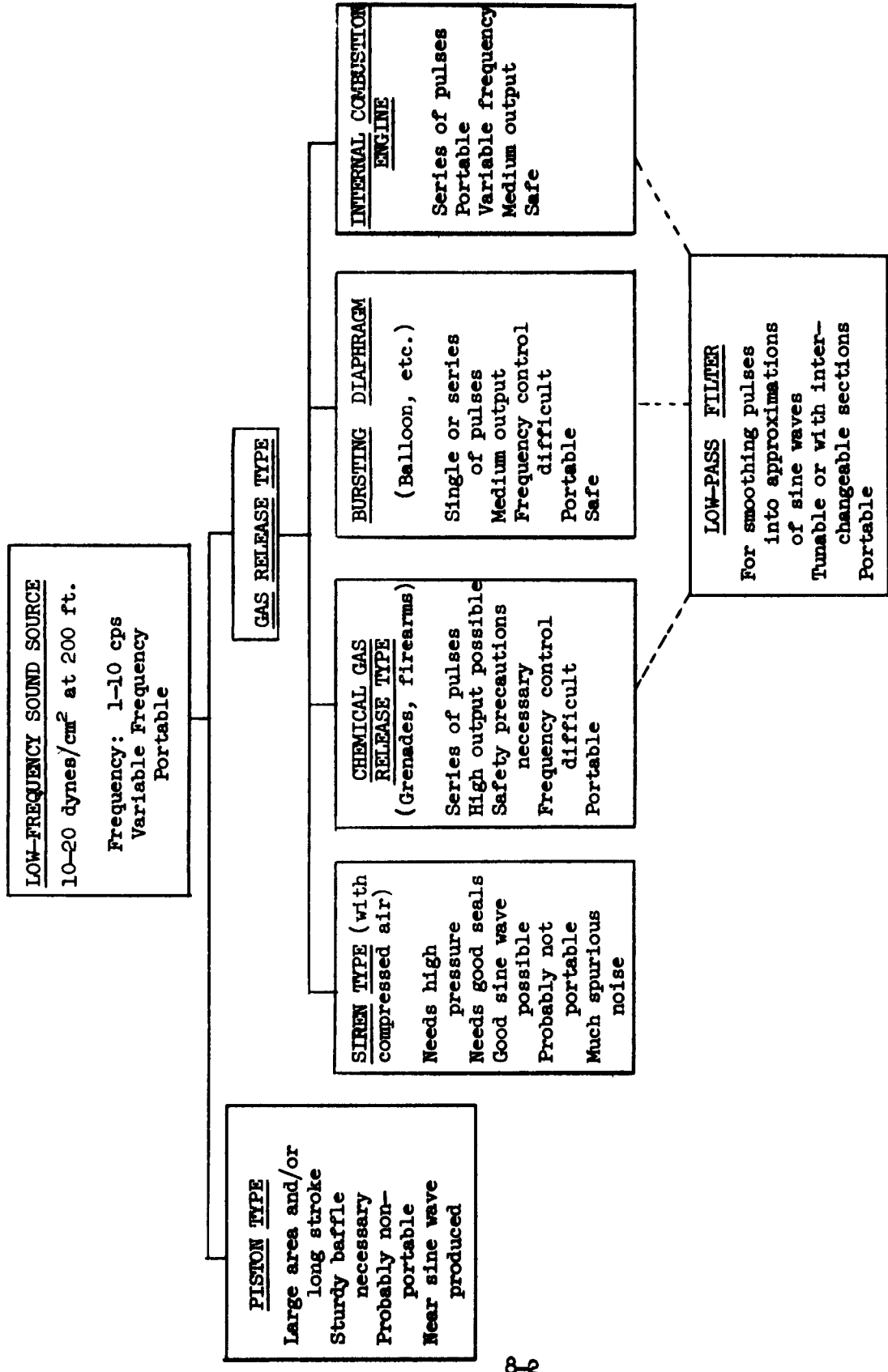Tunable or with inter-
changeable sections
Portable

Figure 8-1

8-2

Some sort of repeating firearm with a filter (similar to a "silencer")
is also possible. An interesting possible source two or three miles
from Schellenger Lab is a 600-foot smokestack at American Smelting
& Refining Company Smelter, which may resonate at the frequency
we need.

2. Signal-to-Noise Ratio

Methods for increasing the signal-to-noise ratio fall into three
major groupings:

    a. Amplifying signal without increasing noise.

    b. Decreasing wind noise without affecting signal.

    c. Decrease noise pickup during transmission of signal.
       Outlines of these groupings are given in Figures 8-2 and 8-3.

3. Amplifying Signal

Several interesting possibilities are available here. The conven-
tional Helmholtz resonator would increase the desired signal but it
would also increase wind noise of that particular frequency. Directional
microphones, while increasing or keeping constant the signal, would
decrease or eliminate noise from any direction other than that of the
signal. Of course the approximate direction of the signal must be
known. The general drawback to these methods is that their size is
prohibitive at low frequencies. This does not hold for velocity micro-
phones (ribbon or pressure gradient). Outputs from an array of

Figure 8-2

8-4

DECREASE WIND NOISE

DECREASE EFFECTS OF WIND

LIMIT BANDWIDTH
- Electronically
- Acoustically—two chambered microphone

STREAMLINING
Decreasing turbulence in wind of uni-form velocity

AVERAGING
Decrease noise caused by fluctuations in wind velocity.
- Pipes
- Screens
- Individual Arrays
- Large Area Microphone

DECREASE WIND

TIME OF DAY
Operate when wind is usually minimum

PLACEMENT (Geographical)
- Utilize optimum ground contour (level plains, holes)
- Utilize optimum ground cover (trees grass, etc.)
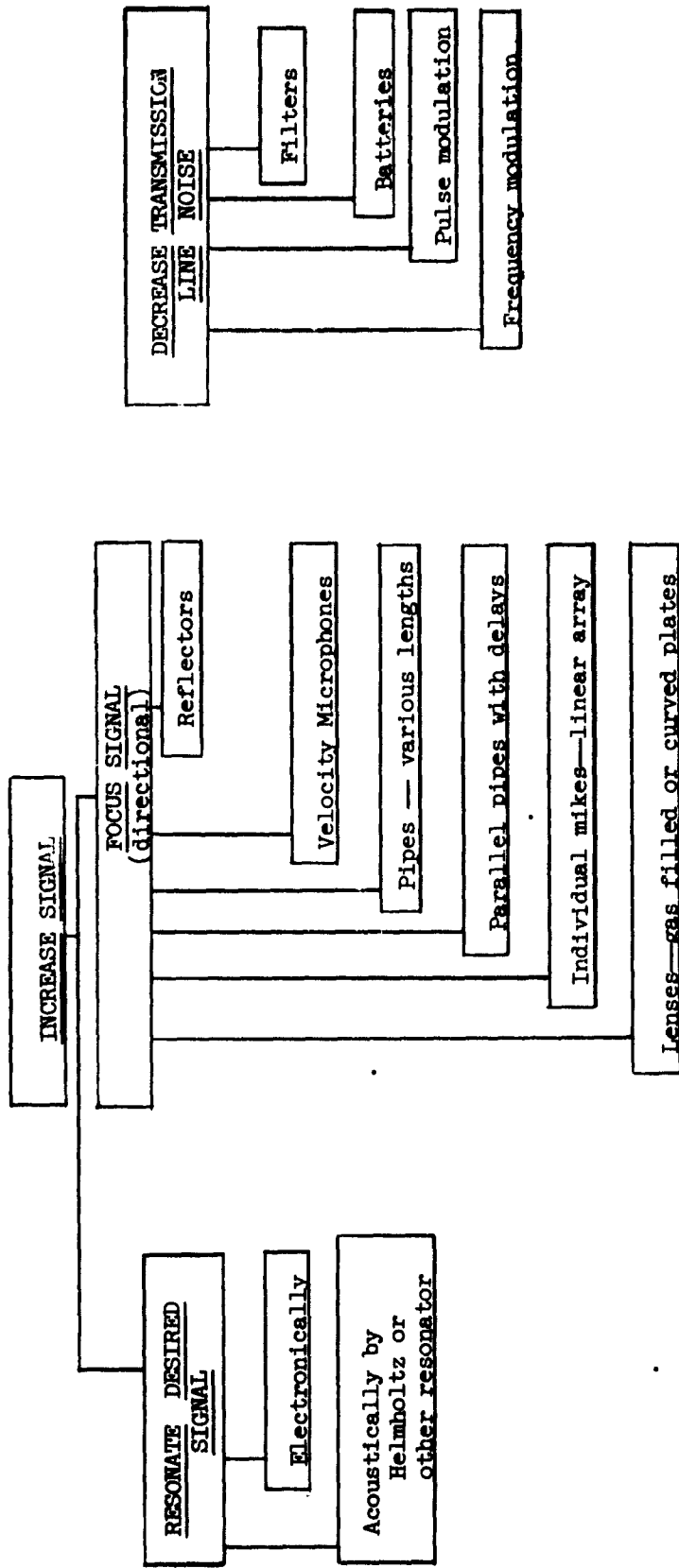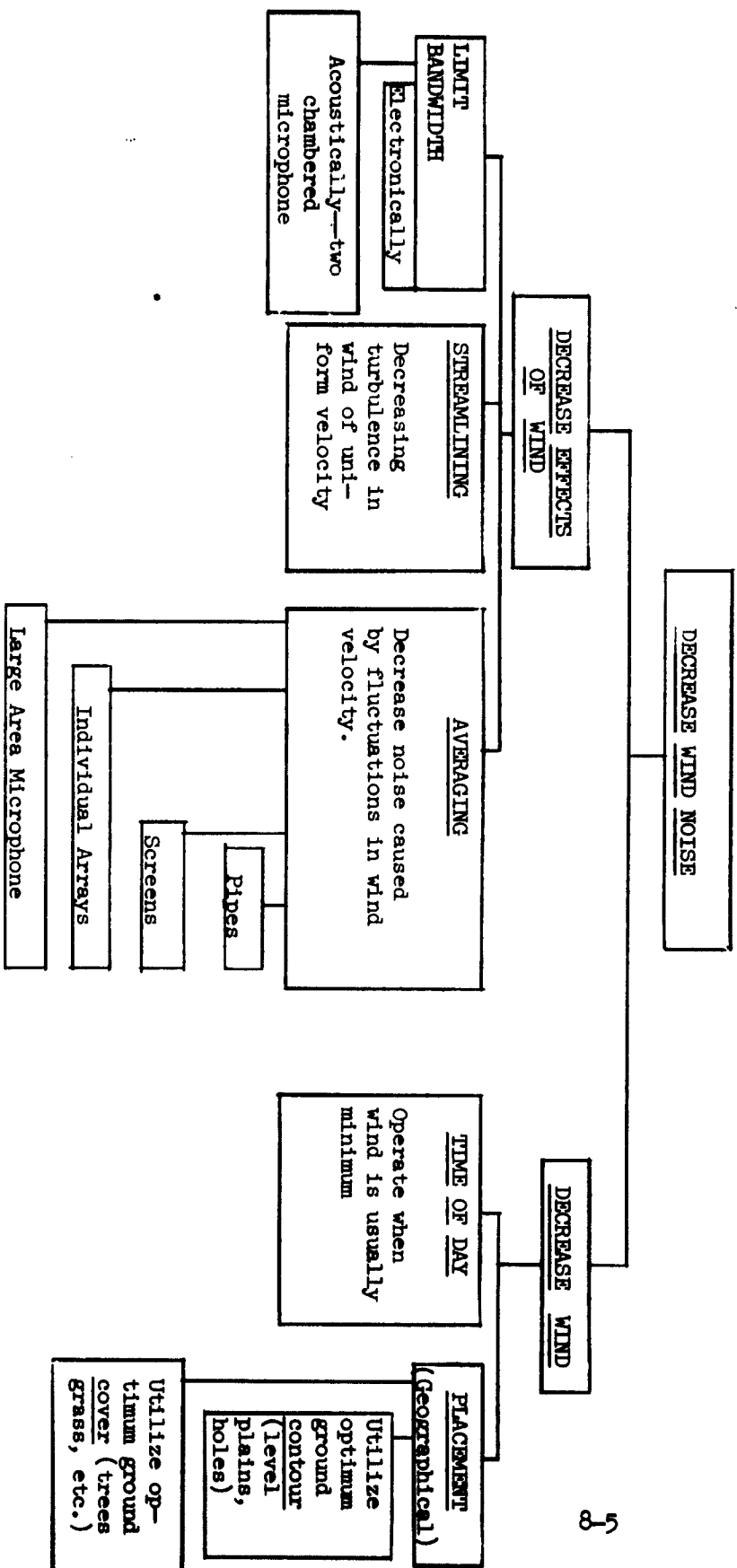
Figure 8–5

microphones can be combined so that the array is directional. Low-frequency reflectors would normally be considered too large to be useful but recent tests here showed an 18 db gain for a parabolic reflector having overall dimensions of the order of 1/3 of a wavelength. Perhaps more design would reduce the size even further.

4. Reducing Wind Noise

Most of the methods for reducing wind noise are familiar. Mike Izquierdo of Schellenger has developed a microphone which by varying the size of the sound-entrance hole and the back-up chamber hole limits the band width of frequencies detected. By "tuning" this microphone to the signal frequency, wind noise of any other frequency is lessened or eliminated. It may also be possible to average wind over a large area by using a rigid cover with very small holes over its surface. Such holes would restrict high-frequency sounds while easily passing any low-frequency sound coming in nearly vertical. Further work is also planned to determine whether any improvements can be made in the pipe array presently in use.

El Paso is a most favorable location in which to conduct these signal-to-noise tests. A wide variety of contour variations are available. Wind in the area tends to be extreme--either high or low depending upon the time of day. Thus by properly timing tests, a variety of wind noise levels may be obtained in a relatively short time.

8-6

SECTION IX

CONCLUSION

IX. CONCLUSION

1. Microphone Improvement

Under Modification 9, the ground capacitor microphones were drastically changed resulting in a substantial improvement. The microphone elements were reassembled with a few physical changes and several new assembly techniques. Addition of the baffle behind the element eliminated oscillations due to heat in the microphone can. Resonances in the acoustic coupling chamber were eliminated by removing the styrofoam. Inverting the microphone on three legs improved the weatherproofing--direct rain and sand can no longer leak into the sound entrance. All circuit boards were resoldered and sprayed with clear Krylon for more durability and better weatherproofing. A new circuit board was designed for several microphones which greatly reduced the 60-cycle ripple. With these modifications, the microphone system is now more durable, rugged, reliable, and accurate. All thirty Model 2 microphones were modified and sixteen Model 1 microphones were rebuilt into Model 2's. An instruction manual was published covering these microphones.

2. Calibration

Two methods of field calibration have been developed under this contract. The first is a portable pistonphone intended for bench use at some central supply station. The second device is a small unit to fit

on the top of the microphone intended for use at each field station. The accuracy, stability and dependability of the portable pistonphone will be greater than that of the field calibrator. One portable pistonphone and field calibrator were delivered to White Sands.

3. Alternate Sensors

Several alternate sensors were considered. Acoustically-tuned microphones, hot-wire microphones, a bridged "T" circuit and an FM system were studied. Each has some advantages. The "tuned" and hot-wire microphones limit the bandwidth of the microphone. By reducing the bandwidth, much noise is also eliminated. The bridged "T" circuit could have a much lower frequency response. An FM system would respond to low frequencies and be easily transmitted, but it is less sensitive.

Many multiple-unit sensors were considered (see Section VIII, Future Work) but none were built. No comparison as to the relative merits of comparatively large sensors could be made due to the inavailability of testing equipment. An attempt was made to construct a low-frequency sound source, but with only small success.

4. Transmission

A system was constructed to modulate the frequency of pulses with the output from a capacitor microphone. The pulses were

transmitted and put into a discriminator. The output had some noise of the pulse frequency. The system was insensitive to amplitude changes and line noise. Moderate line losses could be tolerated.

An FM system from which the signal could be easily transmitted was attempted. However, an adequate detector was not located.

Further efforts to improve and finalize the design of either of the above systems were abandoned. The cost of the system for each array of microphones appeared high when compared to the benefits to be gained. It was also felt that time could be spent more profitably investigating other areas.

5. Other Testing

To determine various characteristics of the capacitor microphone, tests were made on the microbarograph and pipe array. The microbarograph linearity, frequency response, phase-shift, and transient response were plotted. An indication of the frequency response of the pipe array was also plotted.

6. Future Work

Several problems still exist in the capacitor microphone. Some inexpensive method of making the microphone insensitive to change in line voltage needs to be found. The mylar diaphragm should be more resistant to salty air. Transmission of the signal over wire is still some problem.

A number of other possible ways to obtain more readable signals have suggested themselves during this contract period. They are outlined in the previous section.